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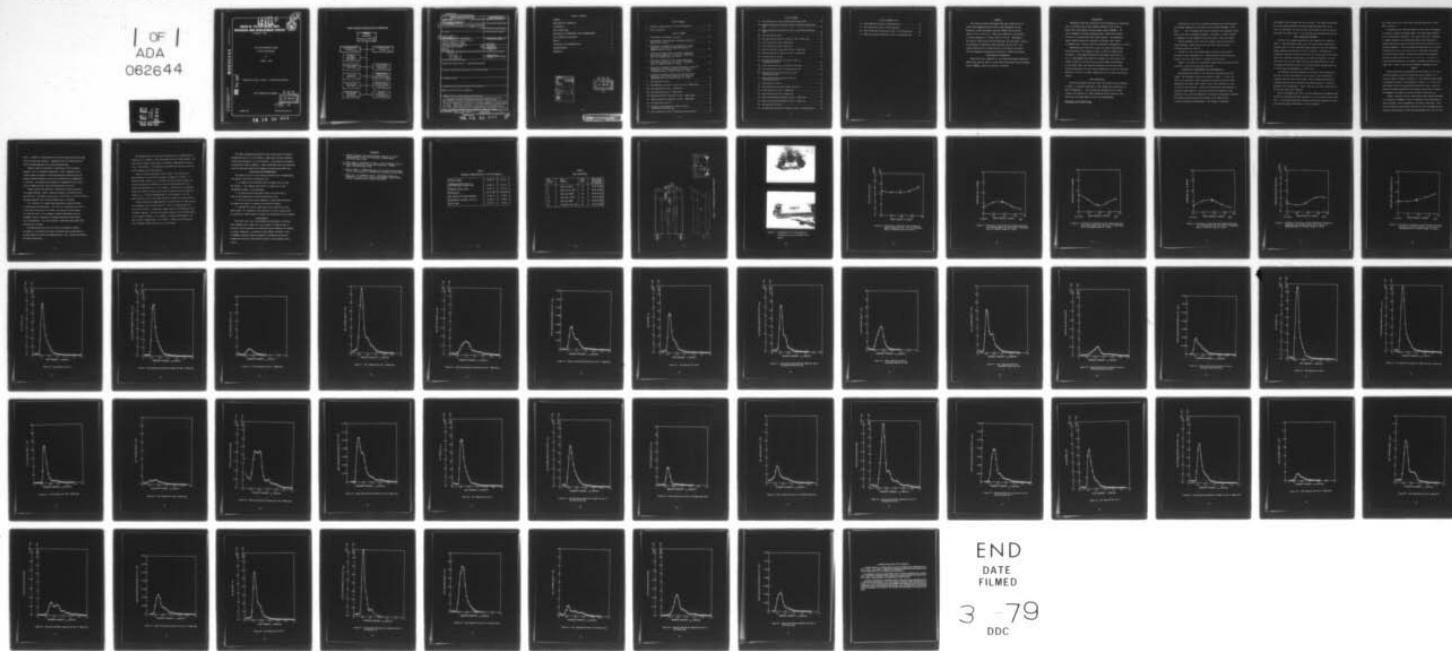
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LOW SPEED SEAKEEPING TRIALS OF THE SSP KAIMALINO, (U)
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OF THE SSP KAIMALINO

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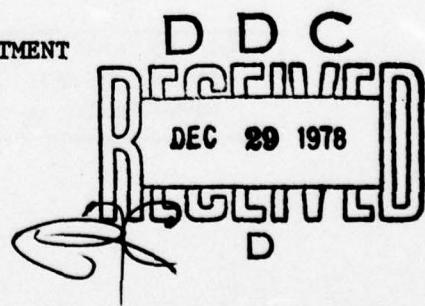
**LOW SPEED SEAKEEPPING TRIALS
OF THE SSP KAIMALINO**

by

JAMES A. FEIN

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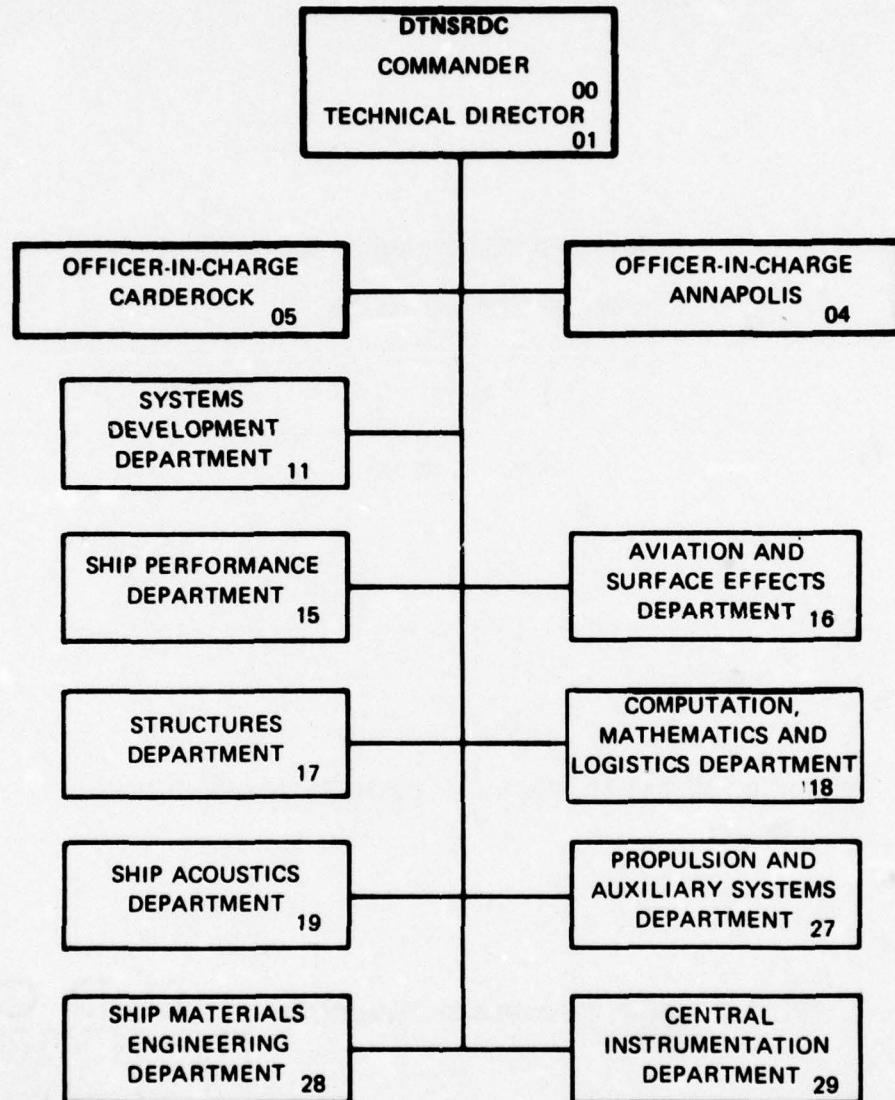
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) DTNSRDC/SPD-0650-04	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) LOW SPEED SEAKEEPPING TRIALS OF THE SSP KAIMALINO	5. TYPE OF REPORT & PERIOD COVERED	
7. AUTHOR(s) (10) JAMES A. FEIN	6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship R&D Center Ship Performance Department Bethesda, Maryland 20084	8. CONTRACT OR GRANT NUMBER(s)	
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command Code 032 Washington, DC	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (11) 1-1170-098	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (12) 63p.	12. REPORT DATE (11) March 1978	
16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED	13. NUMBER OF PAGES 60	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)	15. SECURITY CLASS. (of this report) UNCLASSIFIED	
18. SUPPLEMENTARY NOTES	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) SWATH, Full Scale Trials, Seakeeping		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Full scale low speed seakeeping trials were conducted on the Stable Semi-submerged Platform (SSP) design designated the SSP Kaimalino, a Small Waterplane Twin Hull (SWATH) with an overall length of 87.8 ft (26.7m). Trials were conducted in a Sea State 5 at various headings at a nominal speed of 5 knots. Measurements were made of craft motions and accelerations, and the seaway. Results are presented in significant value and power spectral form. The results establish the low speed motions of the SSP and illustrate the good seakeeping characteristics inherent in SWATH ship designs.		

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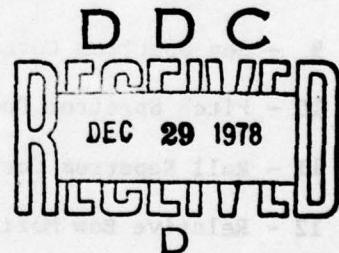
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ABSTRACT

Full scale low speed seakeeping trials were conducted on the Stable Semi-submerged Platform (SSP) design designated the SSP Kaimalino, a Small Waterplane Twin Hull (SWATH) with an overall length of 87.8 ft (26.7 m). Trials were conducted in a Sea State 5 at various headings at a nominal speed of 5 knots. Measurements were made of craft motions and accelerations, and the seaway. Results are presented in significant value and power spectral form. The results establish the low speed motions of the SSP and illustrate the good seakeeping characteristics inherent in SWATH ship designs.

ADMINISTRATIVE INFORMATION

These trials were conducted for the Systems Development Department, SWATH Project Office, David W. Taylor Naval Ship Research and Development Center (DTNSRDC), under the work unit 1-1170-098.

INTRODUCTION

Seakeeping trials were conducted on the SSP Kaimalino in conjunction with a structural loads trials program conducted by the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). The craft, designed by the Naval Undersea Center, (NUC) Pearl Harbor, was built at the Curtis Bay Coast Guard Shipyard. The seakeeping trials reported herein were conducted off Punaluu, Oahu, Hawaii in November 1976. Earlier trials are described in References 1*, 2, and 3.

Experiments were conducted in head, bow, beam, quartering and following seas at craft speeds of about 5 knots in a nominal high Sea State 5. The measured significant wave height varied from 3.2 to 4 m. Measurements were made of the seaway, the craft pitch, roll, relative motion at the bow, vertical and horizontal accelerations at the stable table, and vertical acceleration at the pilot house. This data obtained on the only existing SWATH ship in the U.S. may prove useful in evaluating analytical prediction tools and model experimental results.

CRAFT DESCRIPTION

Principal dimensions and other craft characteristics are presented in Table 1, a detailed discussion of craft design and construction is given in Reference 4. The craft had been modified prior to these trials by the addition of a below waterline blister inboard on each lower hull that added about 25 tons to the displacement.

*References are listed on Page .

Propulsion for the craft is normally provided by two 2230 horsepower gas turbines turning two controllable pitch propellers through a chain drive. Only one engine (and thus one propeller) was operating during these trials due to mechanical problems. The amount of rudder required to compensate for the asymmetric thrust was small at these low speeds.

Control surfaces on the craft were rudders, stern foil flaps and forward canards. These surfaces were held fixed during the data collecting portion of each run.

The SSP is a twin strut SWATH design with most of the buoyancy provided by lower submerged hulls. Another feature of this particular design is the full span stern foil between the lower hulls.

Figure 1 is a sketch of the Kaimalino showing motion and acceleration transducer locations and principal dimensions.

DESCRIPTION OF MEASUREMENTS AND INSTRUMENTATION

Measurements were made of craft motions, accelerations, and the seaway. The transducer locations are shown in Figure 1. Pitch, roll, vertical accelerations, surge acceleration and sway acceleration were measured at the stable table located on the craft centerline as close to the CG as was practical. Vertical acceleration was also measured in the pilot house (Frame 5). Relative bow motion was measured 3 feet forward of the craft bow by means of an ultrasonic displacement transducer. The vertical absolute motion was measured at the same point by a double integrating accelerometer. The attempt to determine

wave height from the signals was not successful. The seaway was measured by a free floating datowell buoy which telemetered wave data to the craft for recording. The buoy was kept within sight of the craft and in deep water for these trials. It was launched and recovered from the SSP.

TRIAL PROGRAM AND PROCEDURE

The SSP trials program reported here was conducted in a high Sea State 5. Runs were made in head, bow, stern quartering, following and beam seas with two trial conditions being completed at the later heading. Seaway conditions and speed are listed in Table 2. The waves were reasonably consistent over the trial period so all the runs can be considered to be conducted in approximately the same sea condition. The sea spectra for each run were taken from buoy data obtained near the craft. The seaway was observed visually to be unidirectional although there are no directionality measurements to confirm this.

In conformity with the procedure for the other trials conducted on the SSP, the craft was ballasted at zero speed to zero trim and heel conditions each day before tests began. Draft readings were made and recorded along with water temperature and specific gravity in order to determine craft displacement. Table 1 indicates the craft conditions for the day the trials were conducted.

Prior to beginning the trials, the wave height buoy was deployed from the SSP in a position which was intended to be in the center of the trials area. At all times during data collection the relative positions of buoy and craft were under surveillance of a deck observer.

All trials were run in an area where the water depth was at least 600 ft (183 m).

In preparation for each particular run, the craft was steadied on course at roughly the desired speed. The speed varied slightly due to wind and wave conditions. The craft course, set to maintain a constant heading to the predominant seaway, was determined by observations from the deck, and wind direction was indicated by an on-board anemometer. Once the heading and speed were set, the data collection portion of a run was executed until about 20 minutes of data had been recorded. Buoy data was recorded simultaneously and used to obtain the sea spectrum for each run. No changes in control surface deflection or propulsion settings were made during these runs. Figure 2 shows the SSP Kaimalino undergoing trials.

RESULTS

The motions, heave accelerations and wave height for the trial runs were analyzed to provide significant values (Figure 3 to 7) and power spectra (Figure 8 through 43). The significant wave height is presented in Figure 3 and tabulated in Table 2. It is seen that wave height did not vary appreciably during the trials. Over the entire trial period significant wave height varied about 0.8 meters. The highest wave height was recorded during the head sea run.

Figure 4 contains the pitch significant values (double amplitude) as a function of heading. Pitch is a maximum in following seas for this low speed. Pitch is minimum but not zero in beam seas. This pitch in beam seas could result from the fact that the seaway was not entirely unidirectional or some coupling between pitch and roll could

exist. Asymmetries between the bow and stern should also lead to some pitch in a beam sea condition. Significant pitch in head seas was of about the same magnitude as in stern quartering seas.

Figure 5 shows the variation in significant roll with seaway heading. Roll is a maximum in beam seas. About 3 degrees of roll (peak to peak) is present in following seas, again indicating lack of complete unidirectionality of the sea or some effects of asymmetries in the ship. The rudders were deflected to compensate for the use of only one engine and this could have caused some of the roll.

Figure 6 gives the variation of significant relative bow motion with seaway heading. Figure 7 shows the change in acceleration with sea direction. The trend in this curve is interesting, as the acceleration increases steadily from following through beam to head seas.

It is difficult to compare these significant values with those of other ships in similar seas. Qualitatively, considering the severity of the waves and the size of the ship, the motions are quite small. In a high Sea State 5 at low speeds a maximum significant pitch of 8 degrees is good, a maximum of 6 degrees significant peak-to-peak roll is exceptional. The craft provided a comfortable and stable work platform for the trials.

The power spectra for the trial runs are presented in Figure 8 through 43. The spectra for each run includes the sea spectrum and the sea spectrum corrected for speed and pitch, roll, relative bow motion, and heave acceleration.

The sea spectra for all runs are consistent with a single peak at a frequency of 0.5 rad/sec. The pitch spectra were all single peaked. The peak occurred within a narrow band of encounter frequencies very close to $\omega_e = 0.65$ rad/sec. The beam sea runs showed much less pitch than the other headings as would be expected.

The roll spectra showed more varied trends. The beam sea runs peaked sharply at an encounter frequency of roughly 0.5 rad/sec. A secondary hump at about $\omega_e = 0.9$ rad/sec was also evident in Figure 35. The quartering sea case (Figure 17) was also double-peaked with the second peak appearing at $\omega_e = 0.75$ rad/sec. The head sea roll spectrum (Figure 22) showed no sharp peaks and the following sea case (Figure 41) peaked at $\omega_e = 0.45$ but showed generally little response. The roll peaks tended to occur at the same frequency as peaks in the wave spectra.

Relative bow motion (RBW) generally had peak values at higher encounter frequencies than the other spectra. This is in keeping with the motion of the craft in 'contouring' longer waves and 'platforming' those at higher frequency. The beam sea results (Figure 12 and 36) showed most of the response between $\omega_e = 0.9$ rad/sec. Figure 30 shows RBM for bow seas to have a primary peak at 0.7 rad/sec. Finally the following sea data in Figure 42 shows a peak at $\omega_e = 0.8$ rad/sec.

The heave acceleration spectra all show a sharp peak at encounter frequencies from 0.5 to 0.65 rad/sec, a sharp peak with some responses is also noted around an ω_e of 0.85 rad/sec. Accelerations are greatest in head and bow seas as expected. These acceleration were all associated with the rigid body motions as no impacts occurred during these runs.

CONCLUSIONS AND RECOMMENDATIONS

The results allow for the following conclusions and recommendations that apply to this craft configuration only:

1. No impacts occurred during these low speed trials in high Sea States 5. The frequency and severity of impacting in other circumstances remain to be determined.
2. No severe motions that might hinder craft operations or lead to sea sickness were recorded during these trials.
3. The trial results can be compared to theoretical predictions and model test results to evaluate the prediction methods.
4. Although the control system would not be effective in this speed range it is recommended that quantitative control system trials be conducted at higher speeds to evaluate the usefulness of such a system.

ACKNOWLEDGMENTS

The author would like to acknowledge the assistance of the Naval Ocean Systems Center, Hawaii Lab in the conduct of these trials; in particular those responsible for operating the SSP Kaimalino are thanked for their cooperation. In addition, Gordon Minard and Ernest Wolfe, of DTNSRDC, provided valuable assistance in obtaining the data and Michael Davis and Jose' Bonilla-Norat aided in the processing of the results.

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1. Stenson, Richard, "Full-Scale Powering Trials of the Stable Semi-Submerged Platform, SSP Kaimalino", DTNSRDC Report SPD-650-01 (April 1976)
2. Fein, James A., and Robert T. Waters, "Control Response Trials of the Stable Semi-Submerged Platform (SSP Kaimalino)", DTNSRDC Report SPD-650-02 (April 1976)
3. Kallio, James A., "Seakeeping Trials of the Stable Semi-Submerged Platform (SSP Kaimalino)", DTNSRDC Report SPD-650-03 (April 1976)
4. Lang, T.G., J.D. Hightower, and A.T. Strickland, "Design and Development of the 190 Ton Stable Semi-Submerged Platform (SSP)" Journal of Engineering for Industry (Nov 1974)

TABLE 1
GEOMETRIC CHARACTERISTICS OF THE SSP KAIMALINO

Overall Length	88.25 ft	26.9 m
Submerged Length, Nose to Trailing Edge of Rudder (AP)	81.25 ft	24.76 m
Submerged Maximum Beam	49.70 ft	15.15 m
Displacement	217.5 LTSW	220.0 MTSW
KG, Height of CG Above Baseline	15.40 ft	4.69 m
Longitudinal Distance, AP to CG	42.46 ft	12.94 m
Draft, mean	15.25 ft	4.69 m

TABLE 2
TRIAL CONDITIONS

Run Number	Mean Heading	Craft Speed	Significant Wave Height ft (meters)
7	Beam Sea (90°)	5.2	12.07 (3.68)
8	Stern Q Sea (45°)	5.6	10.90 (3.32)
9	Head Sea (180°)	4.4	13.62 (4.15)
10	Bow Q Sea (135°)	4.8	11.74 (3.58)
11	Beam Sea (90°)	5.0	10.91 (3.32)
12	Following Sea (0°)	6.0	11.65 (3.55)

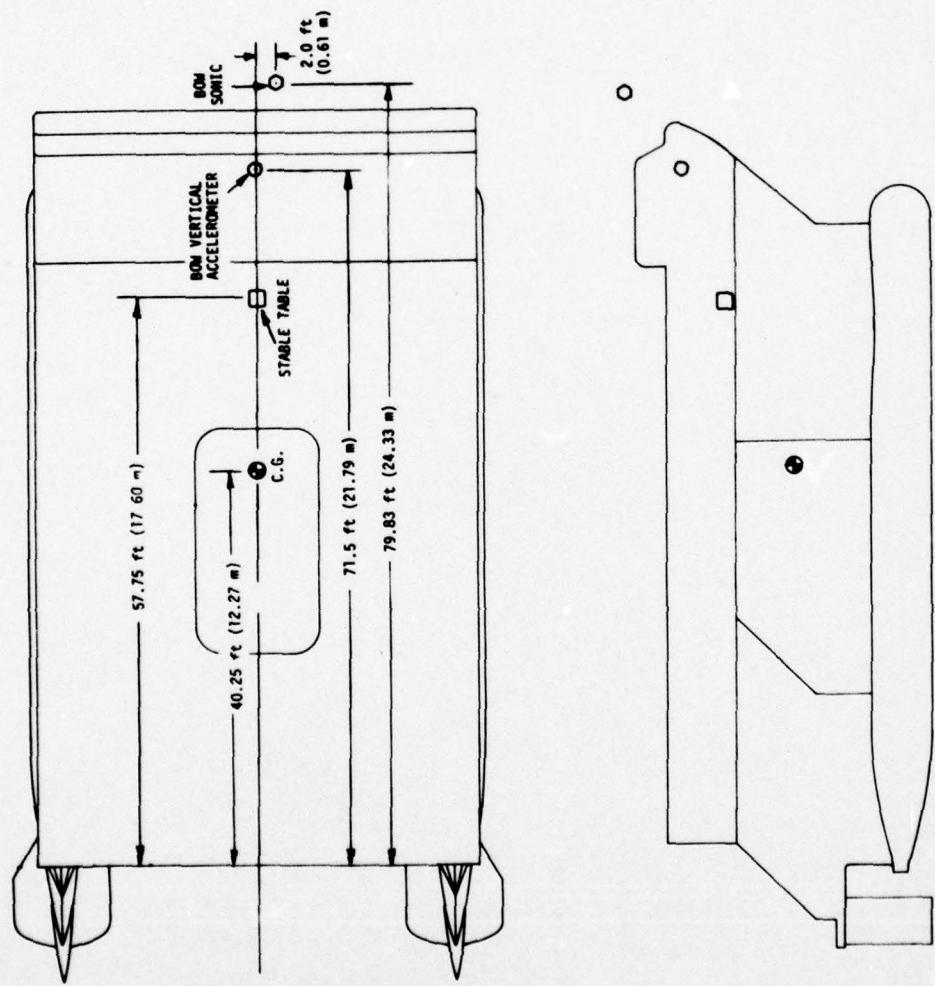
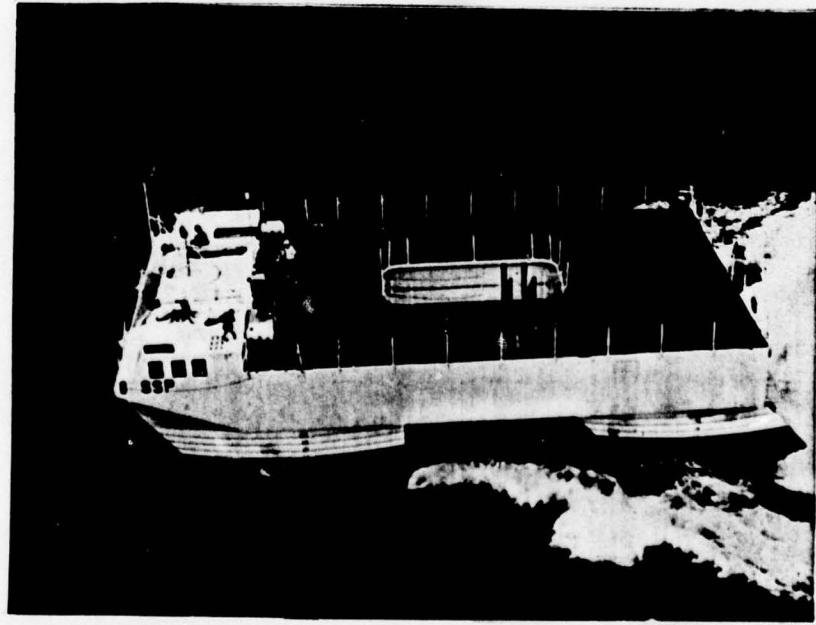
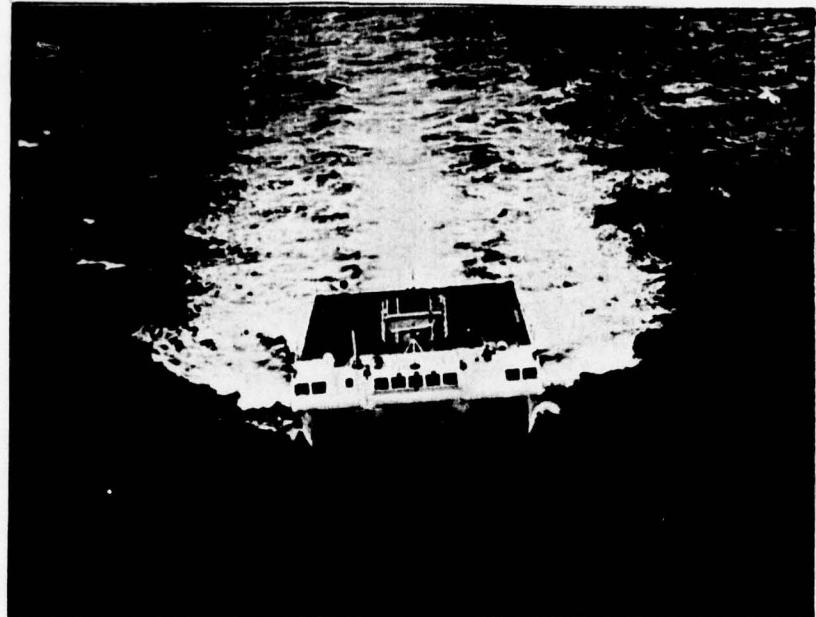


Figure 1 - SSP Kaimalino Transducer Locations



**Figure 2 - Photographs of the SSP Kaimalino
Undergoing Trials off Mokapu Point,
Hawaii**

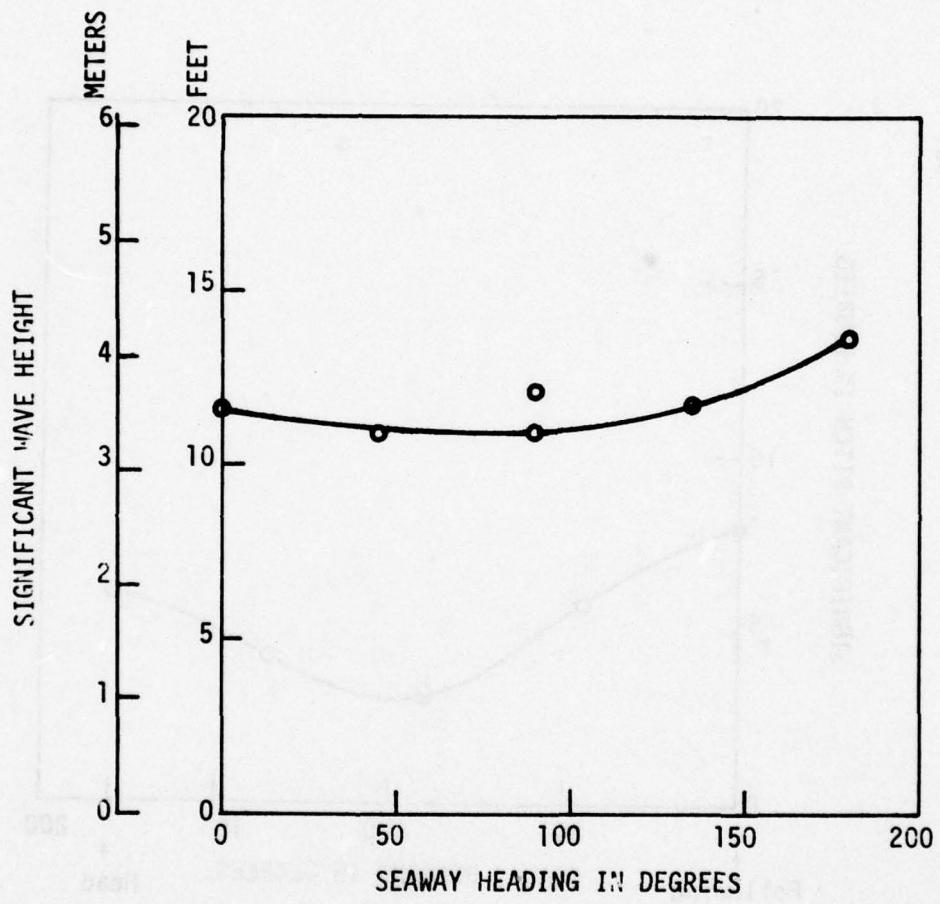


Figure 3 - Variation of Significant Wave Height with Seaway Heading for the Series of Seakeeping Runs at a Nominal Speed of 5 Knots.

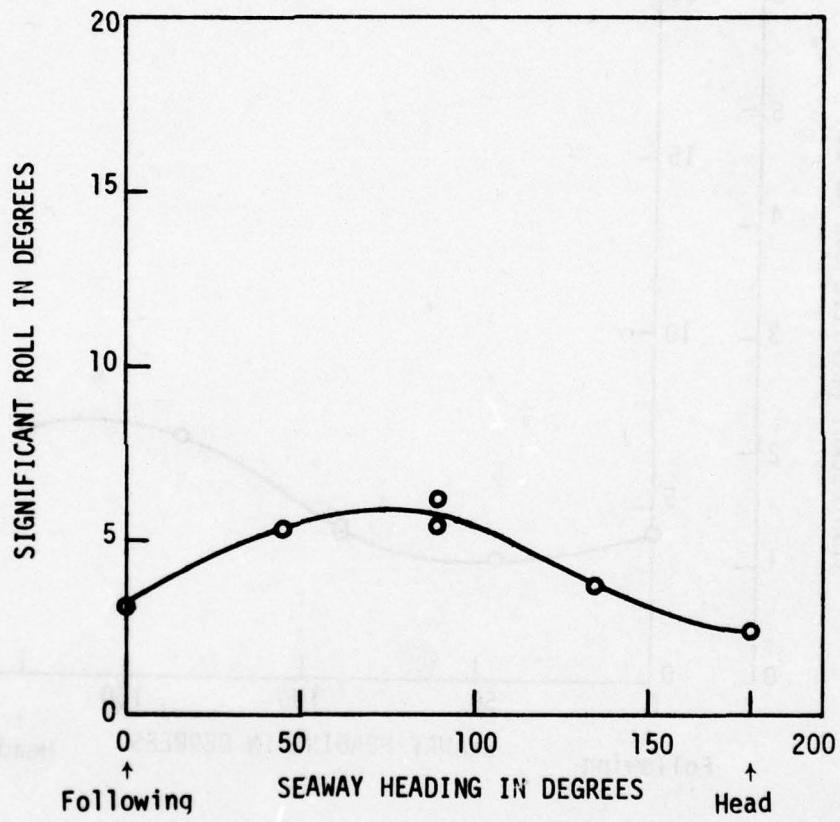


Figure 5 - Variation of Significant Roll Double Amplitudes with Seaway Heading for the Series of Seakeeping Runs at a Nominal Speed of 5 Knots.

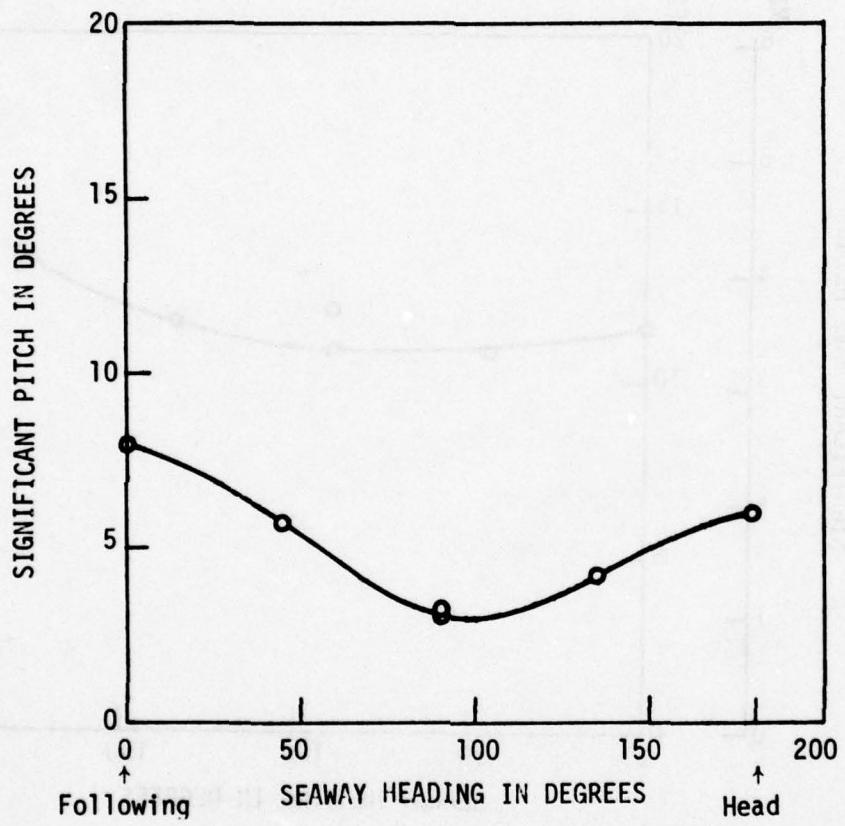


Figure 4 - Variation of Significant Pitch Double Amplitudes with Seaway Heading for the Series of Seakeeping Runs at a Nominal Speed of 5 Knots.

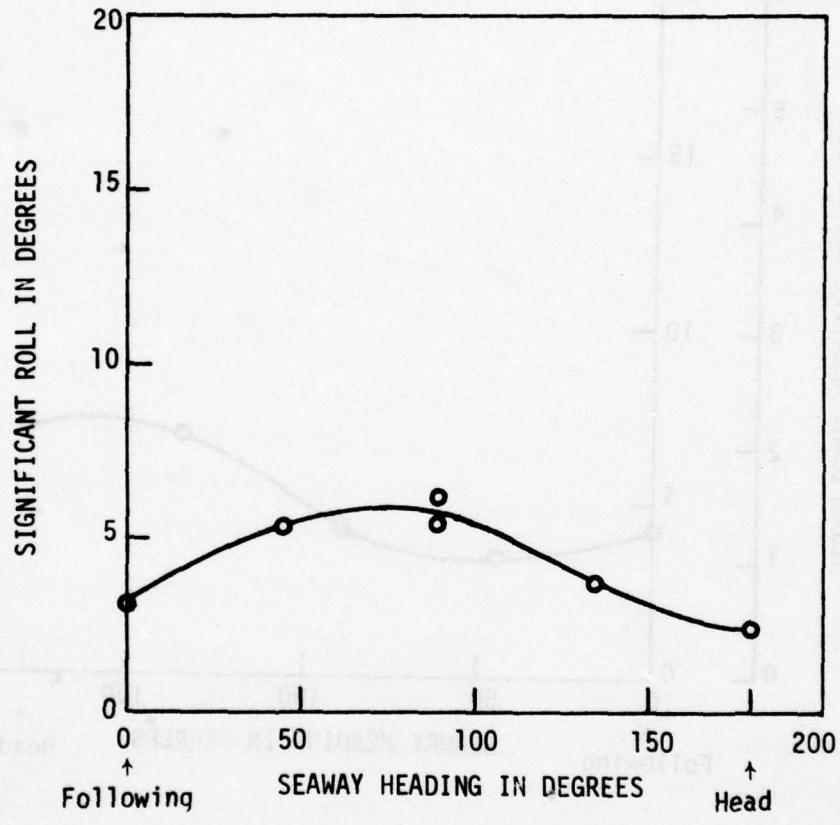


Figure 5 - Variation of Significant Roll Double Amplitudes with Seaway Heading for the Series of Seakeeping Runs at a Nominal Speed of 5 Knots.

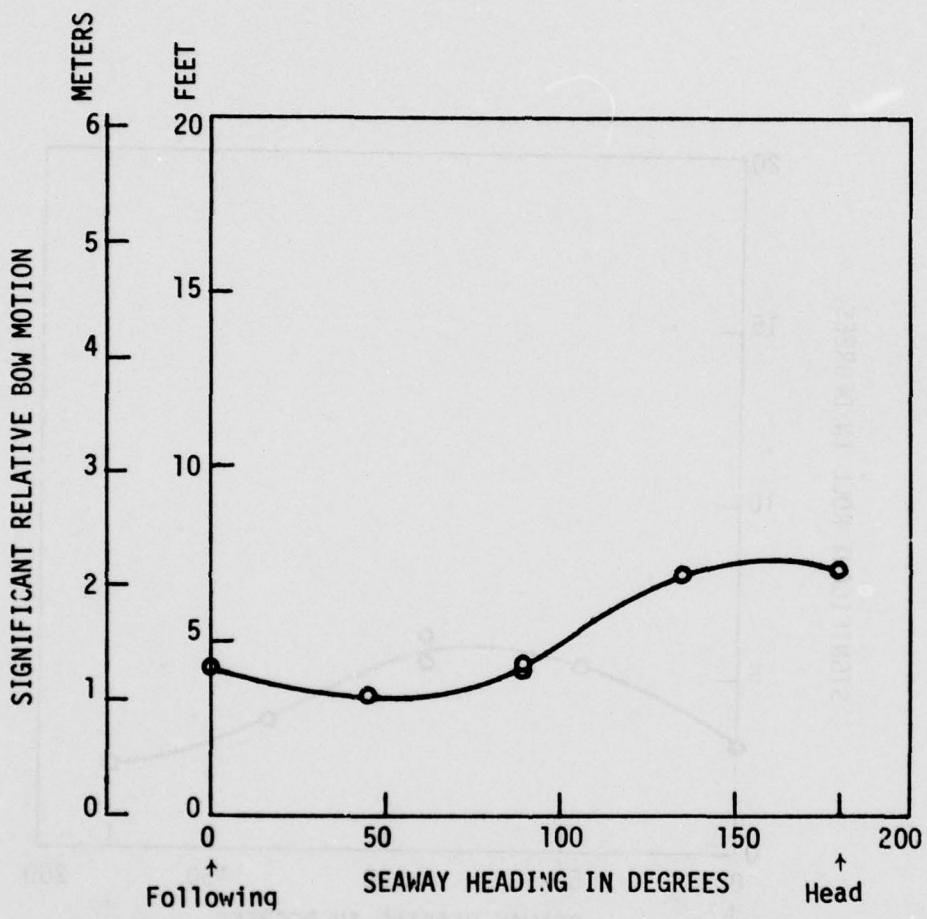


Figure 6 - Variation of Significant Double Amplitudes of Relative Bow Motion with Seaway Heading for the Series of Seakeeping Runs at a Nominal Speed of 5 Knots.

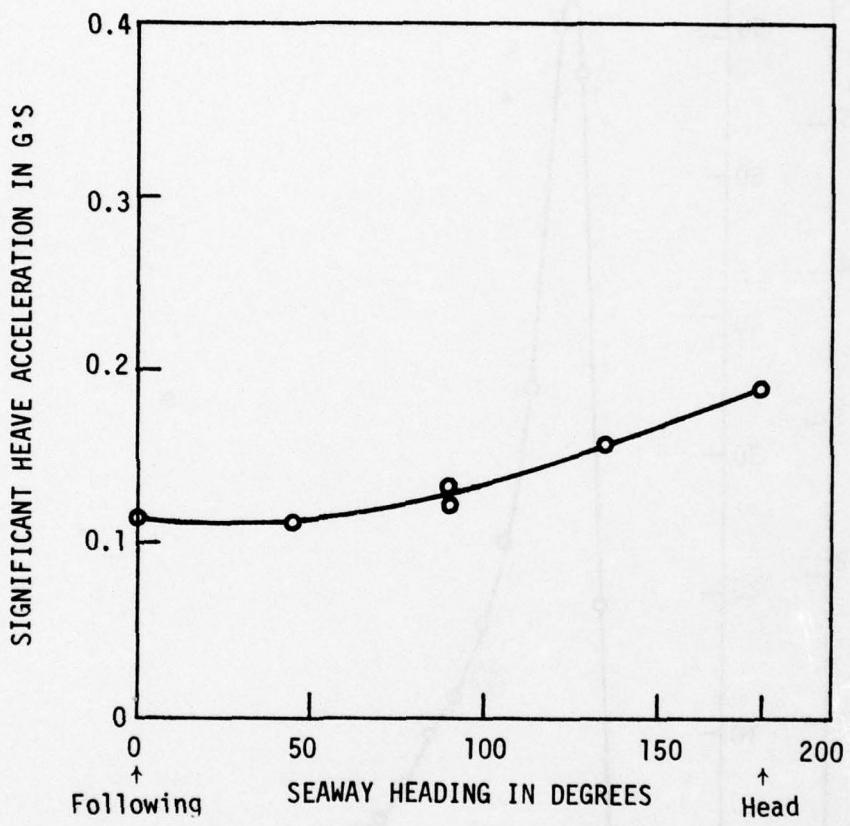


Figure 7 - Variation of Significant Heave Acceleration Double Amplitudes with Seaway Heading for the Series of Seakeeping Runs at a Nominal Speed of 5 Knots.

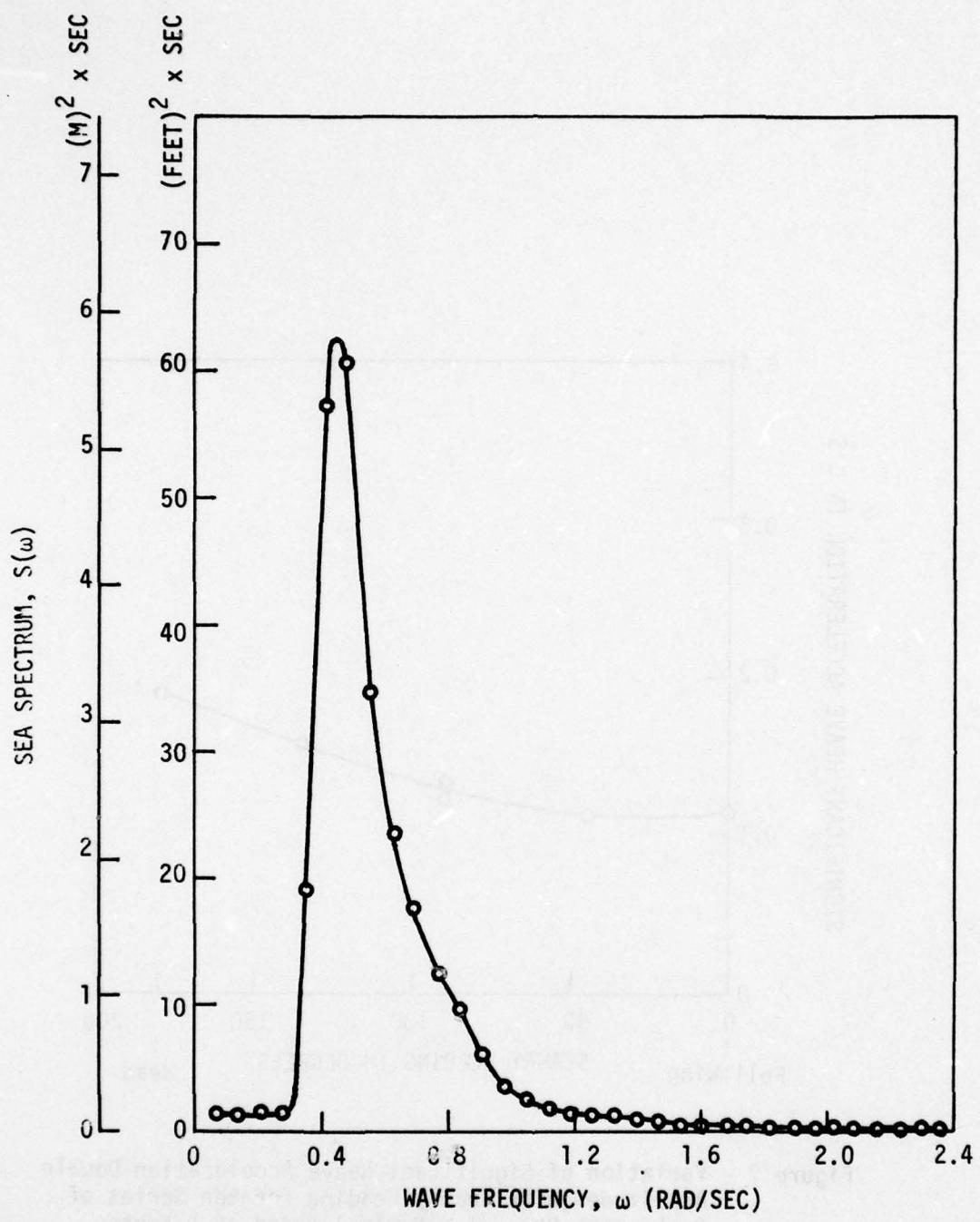


Figure 8 - Sea Spectrum for Run 7.

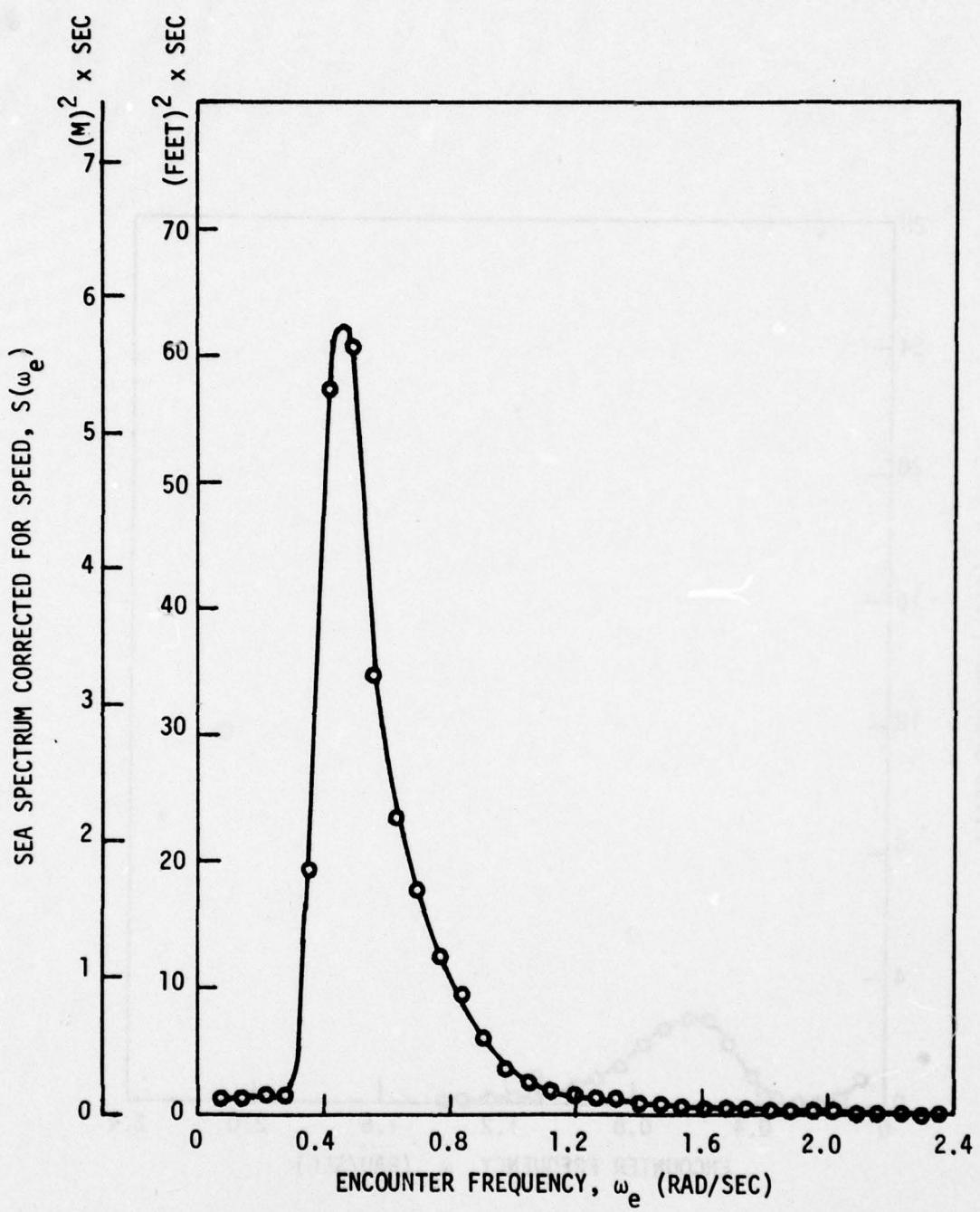


Figure 9 - Sea Spectrum Corrected for Speed for Run 7 (Beam Sea)

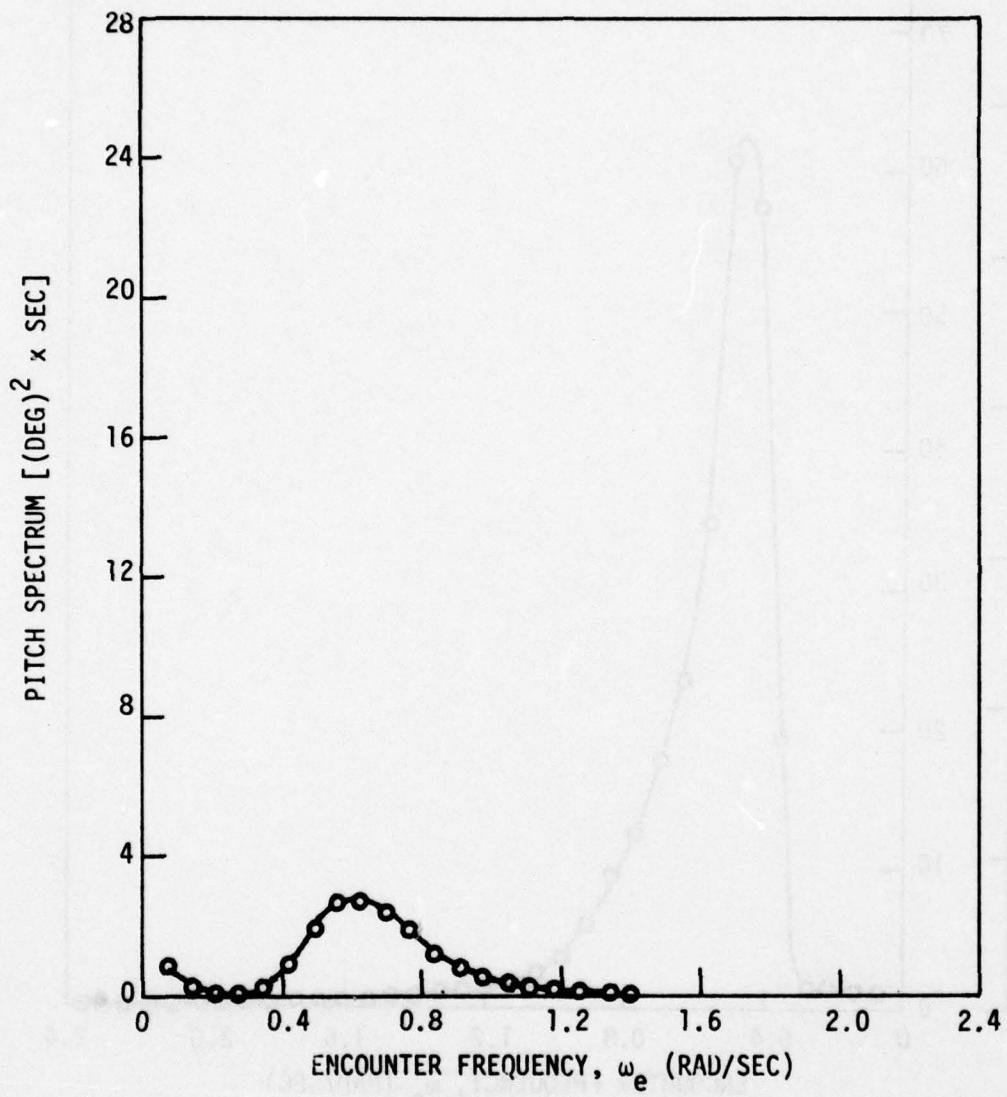


Figure 10 - Pitch Spectrum for Run 7 (Beam Sea)

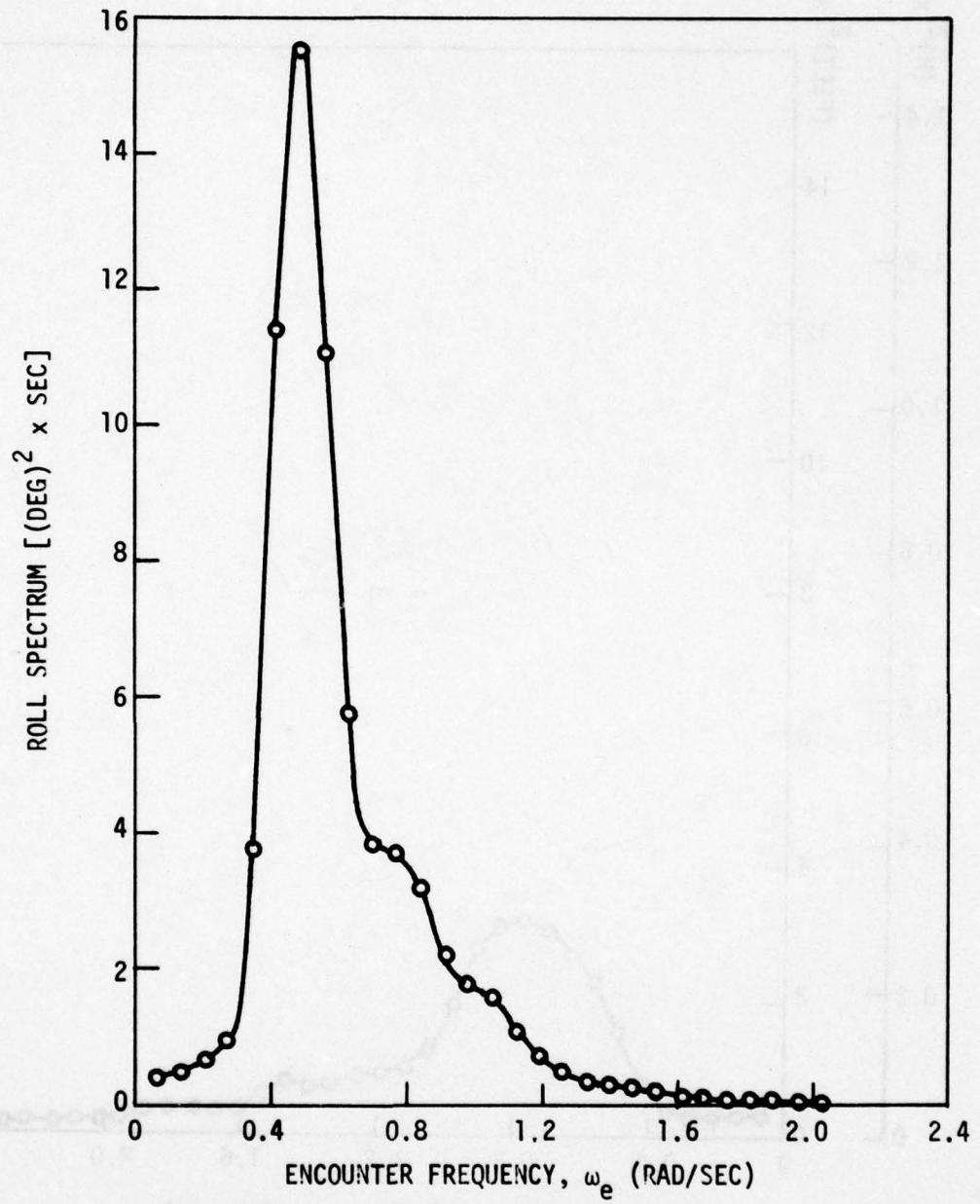


Figure 11 - Roll Spectrum for Run 7 (Beam Sea)

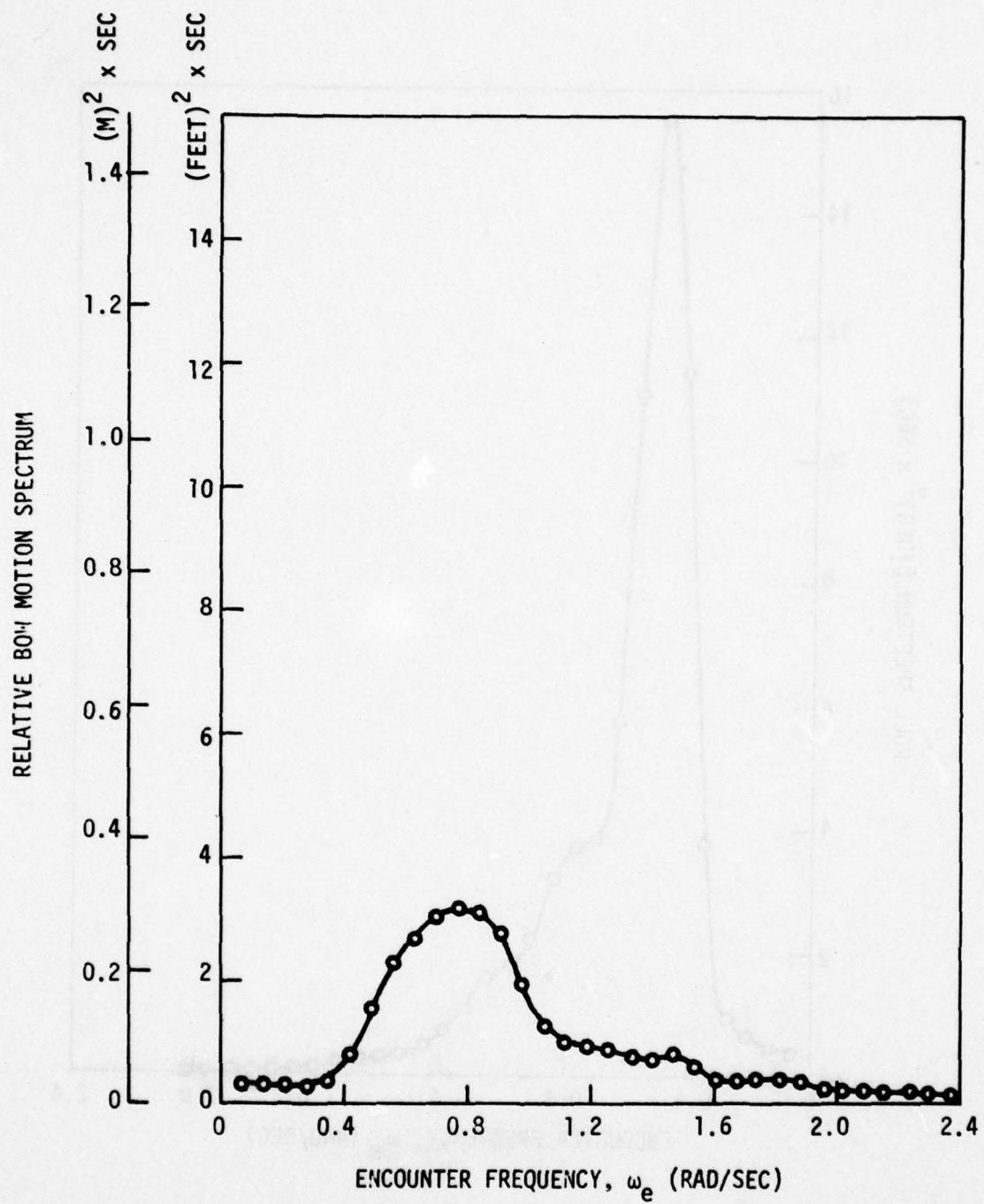


Figure 12 - Relative Bow Motion Spectrum for Run 7 (Beam Sea)

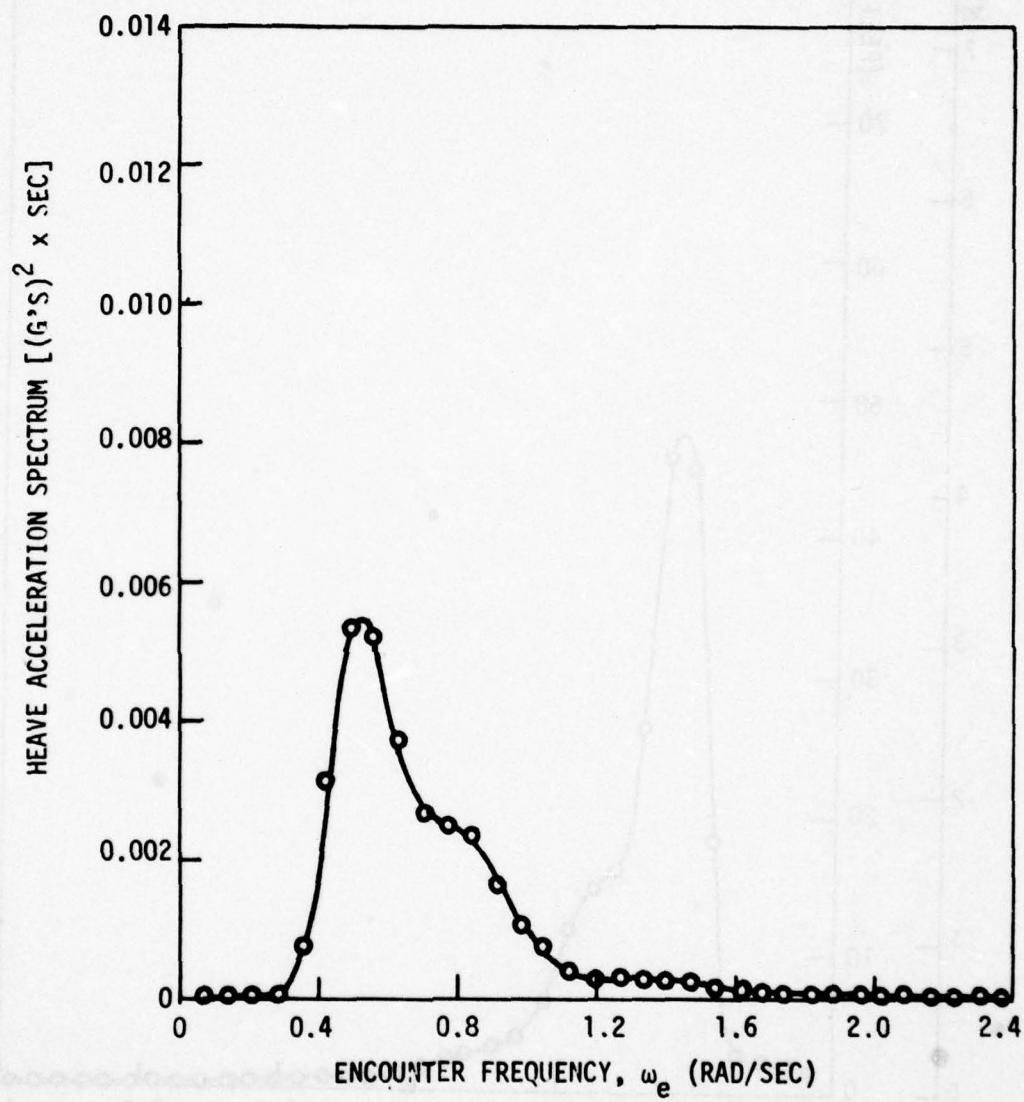


Figure 13 - Heave Acceleration Spectrum for Run 7 (Beam Sea)

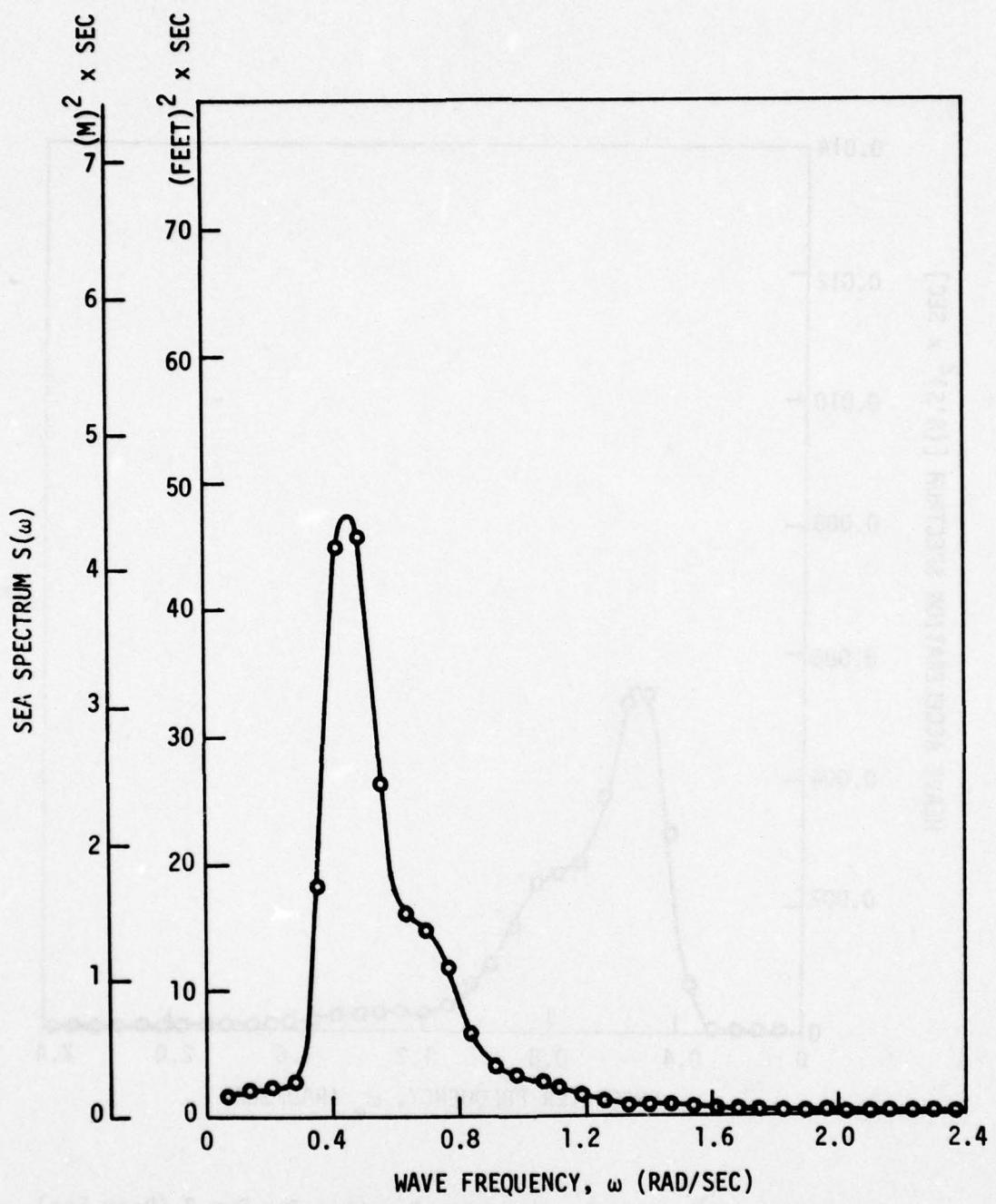


Figure 14 - Sea Spectrum for Run 8

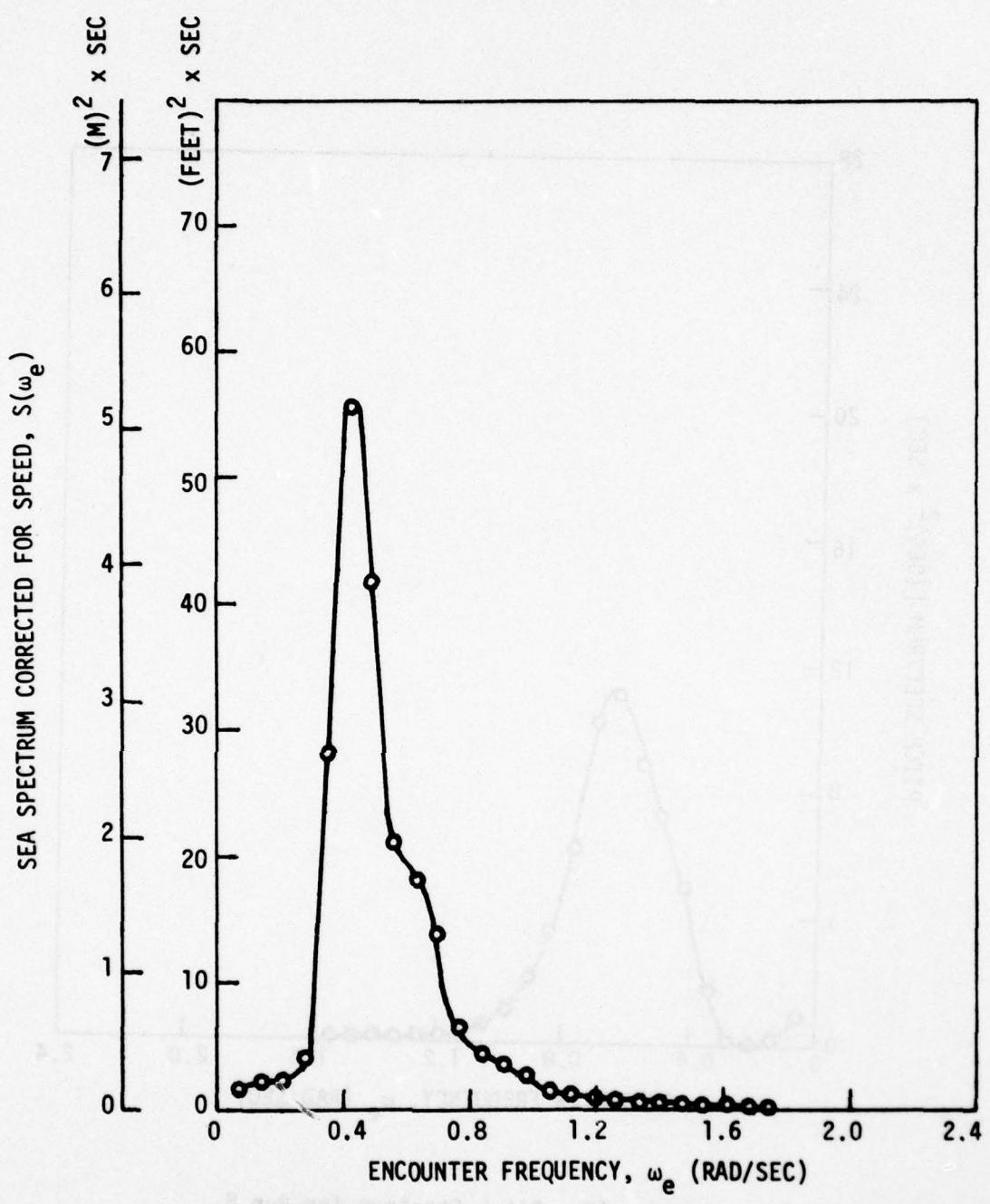


Figure 15 - Sea Spectrum Corrected for Speed for Run 8
(Starboard Quartering Sea)

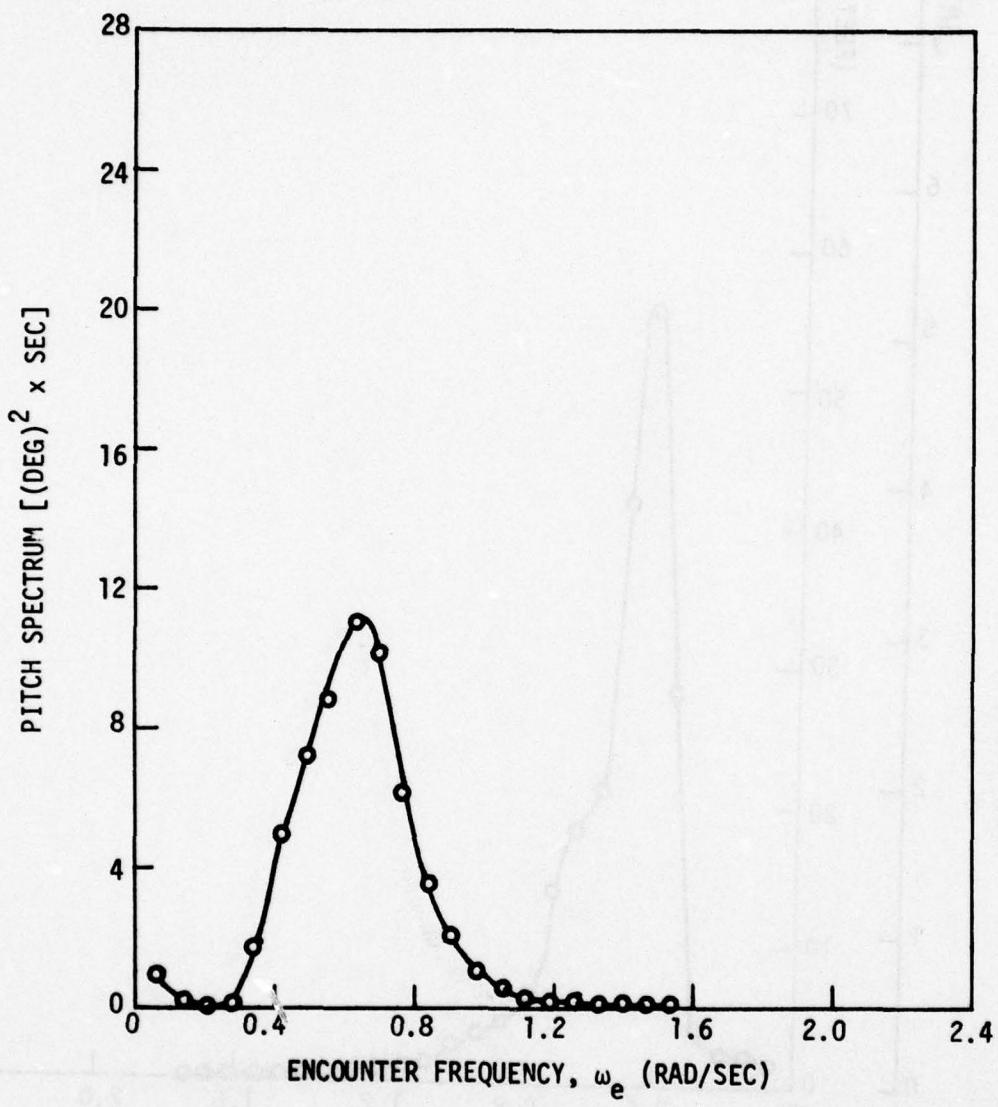


Figure 16 - Pitch Spectrum for Run 8
(Starboard Quartering Sea)

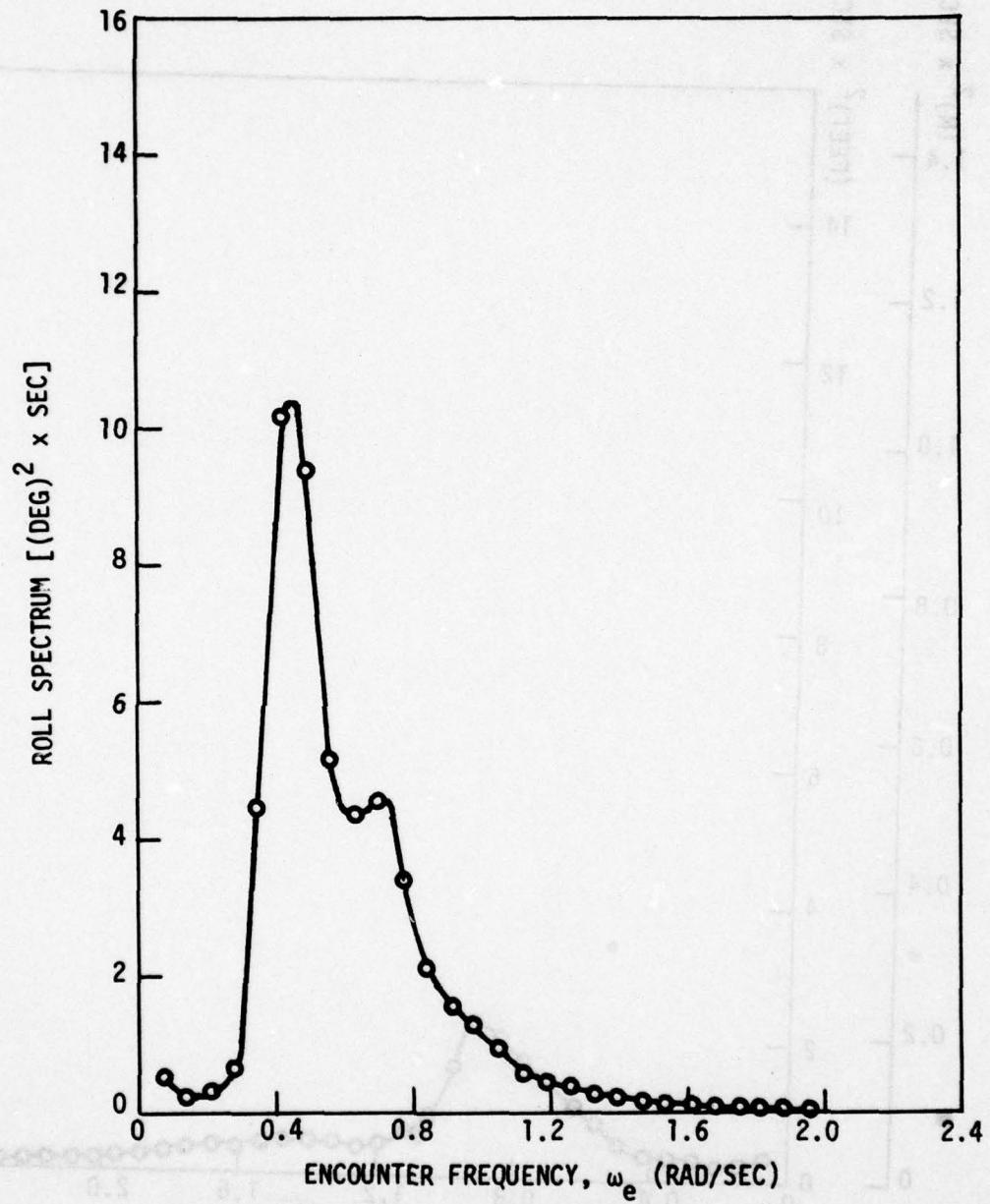


Figure 17 - Roll Spectrum for Run 8
(Starboard Quartering Sea)

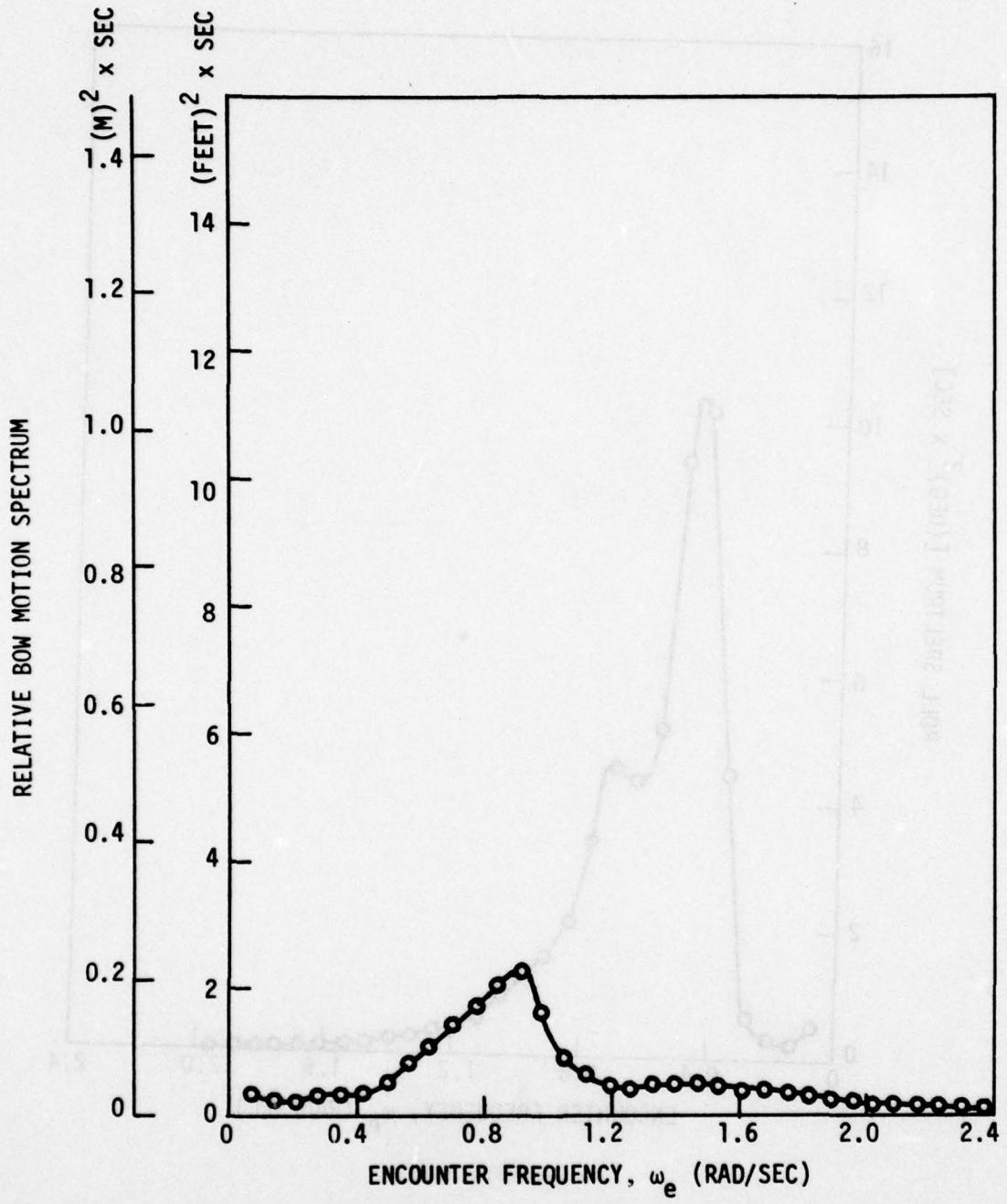


Figure 18 - Relative Bow Motion Spectrum for Run 8
(Starboard Quartering Sea)

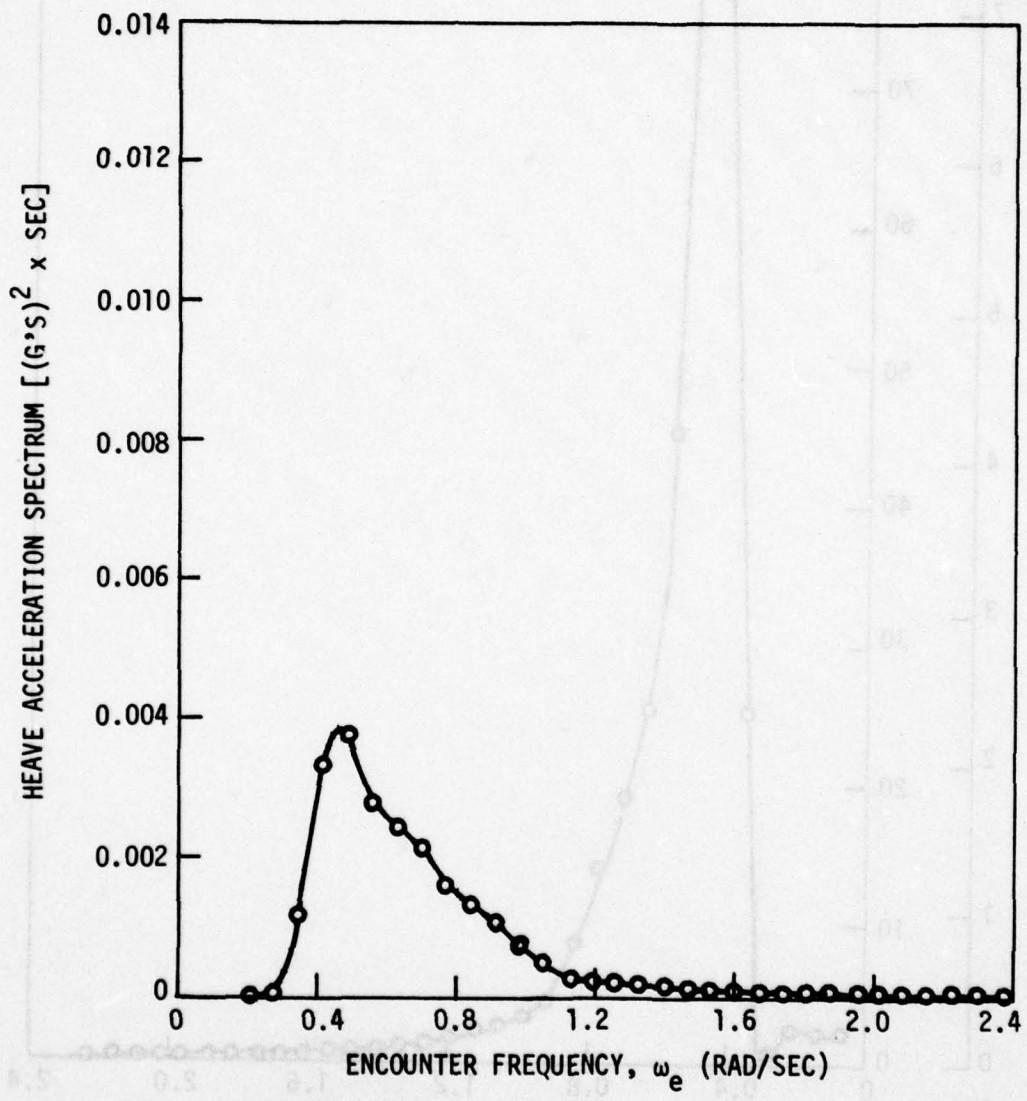


Figure 19 - Heave Acceleration Spectrum for Run 8
(Starboard Quartering Sea)

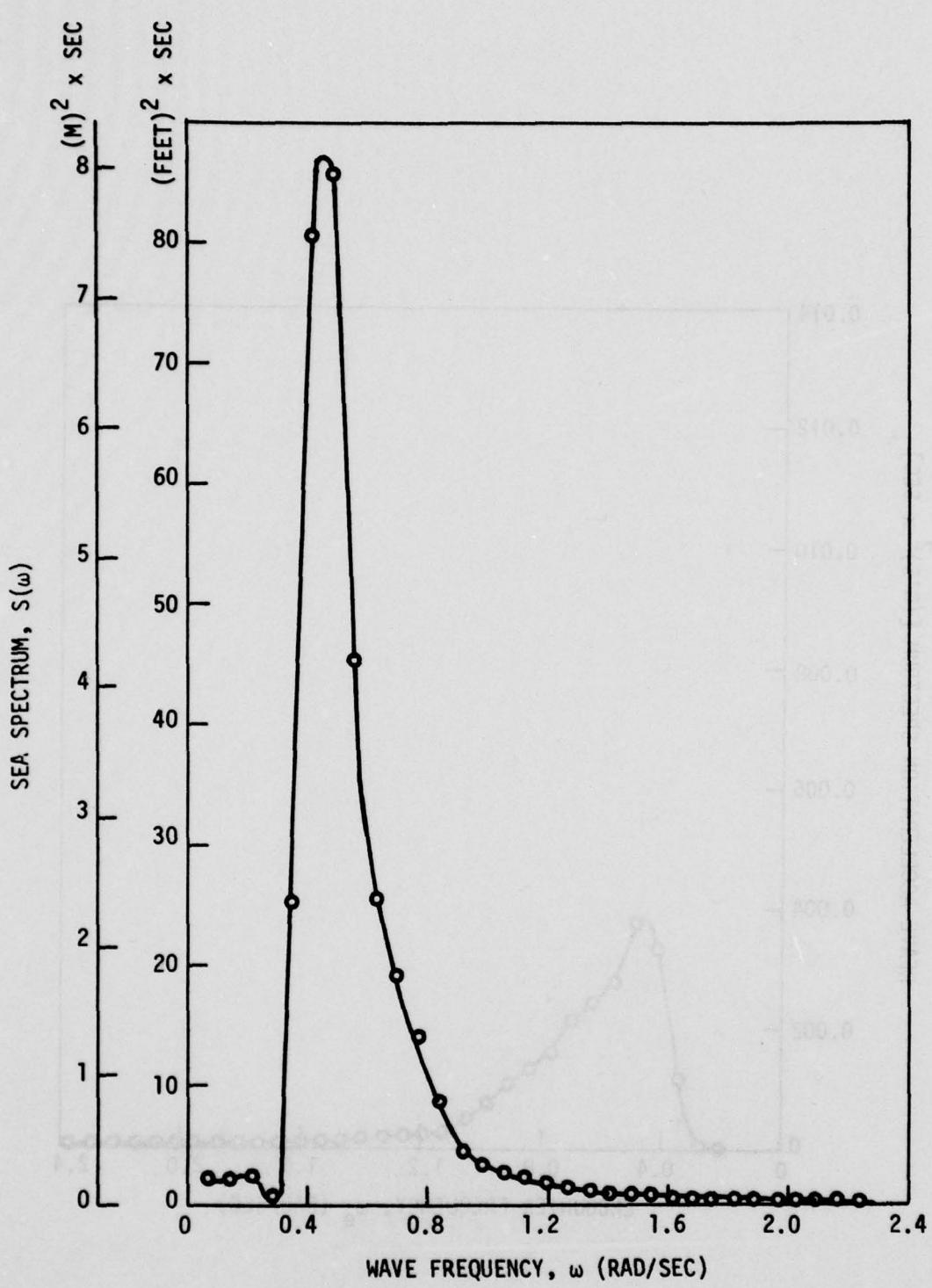


Figure 20 - Sea Spectrum for Run 9

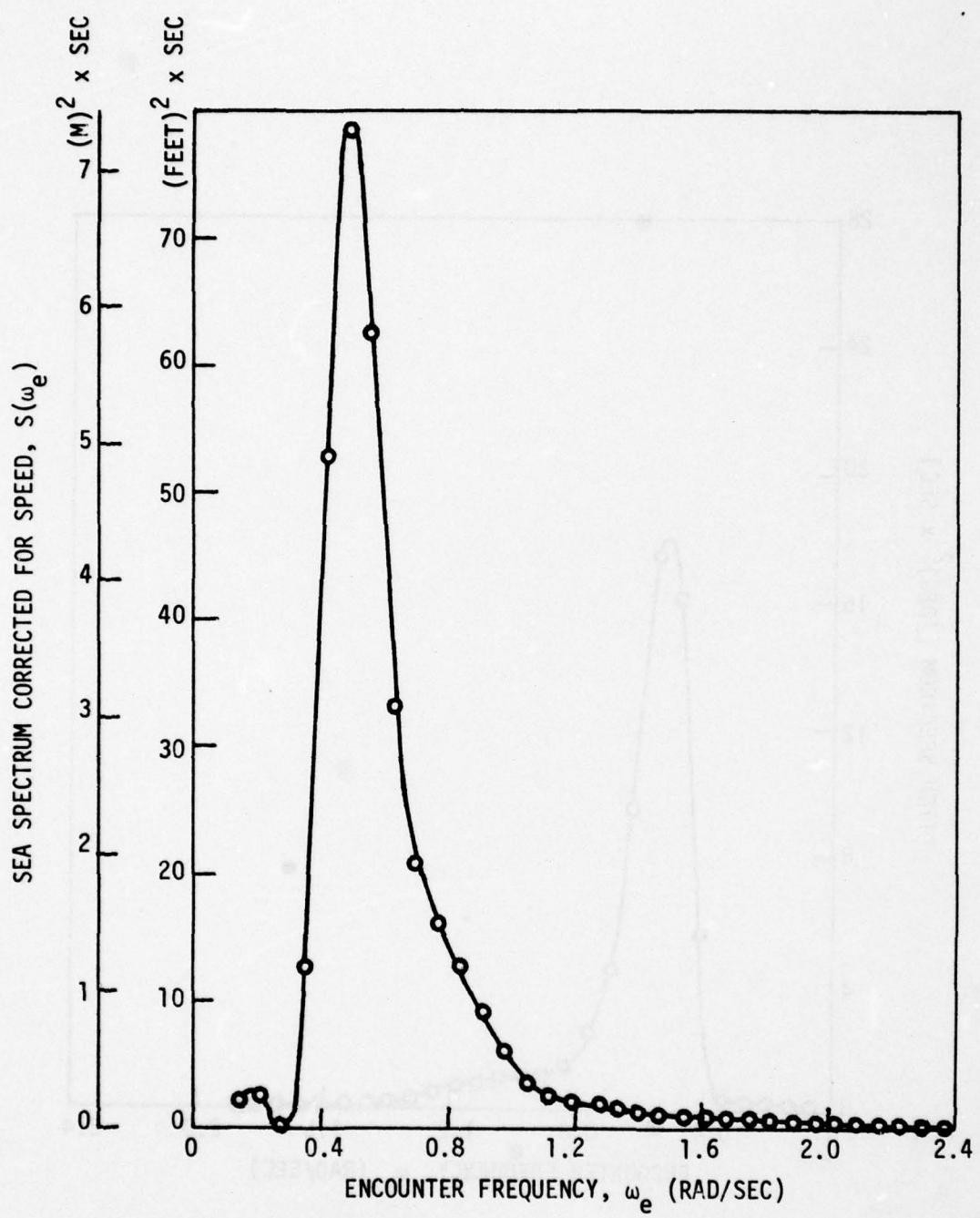


Figure 21 - Sea Spectrum Corrected for Speed for Run 9 (Head Sea)

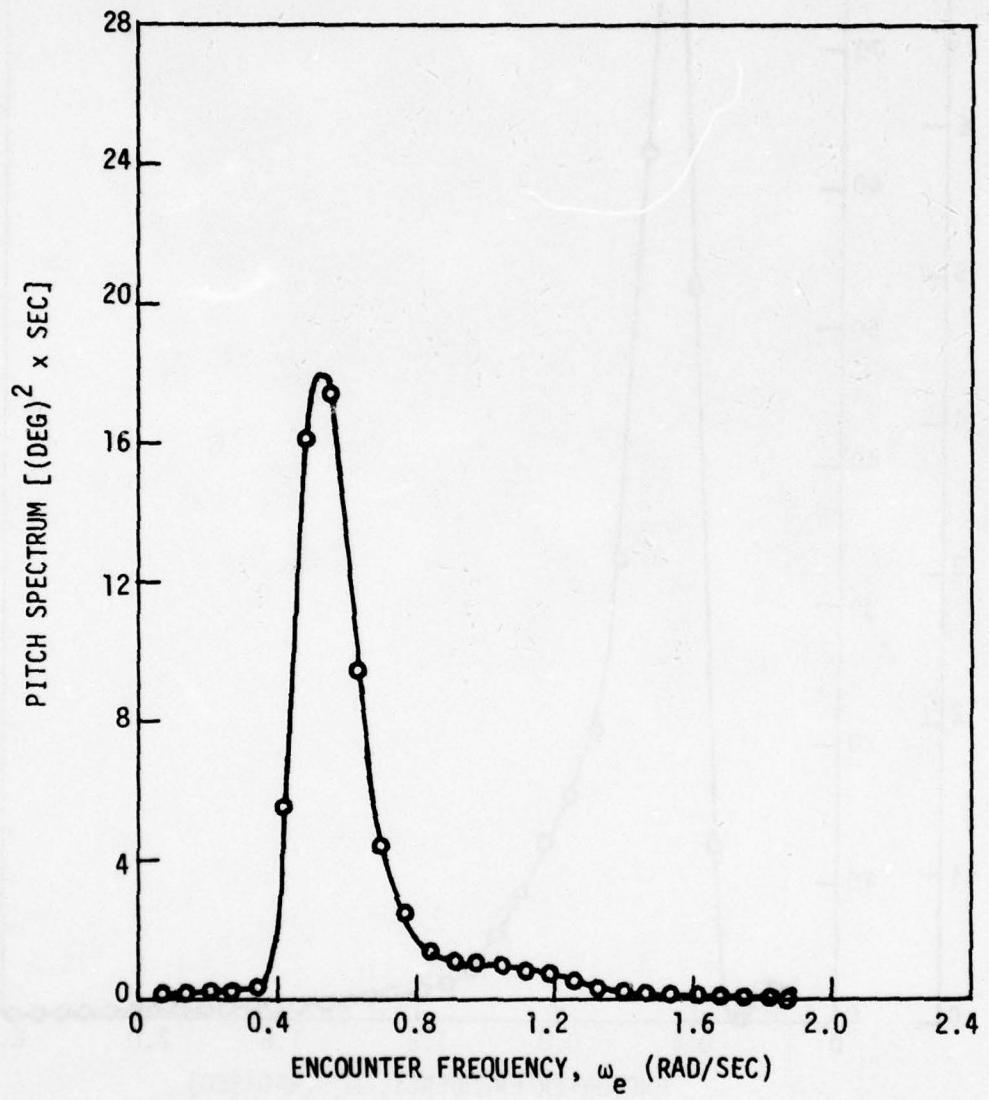


Figure 22 - Pitch Spectrum for Run 9 (Head Sea)

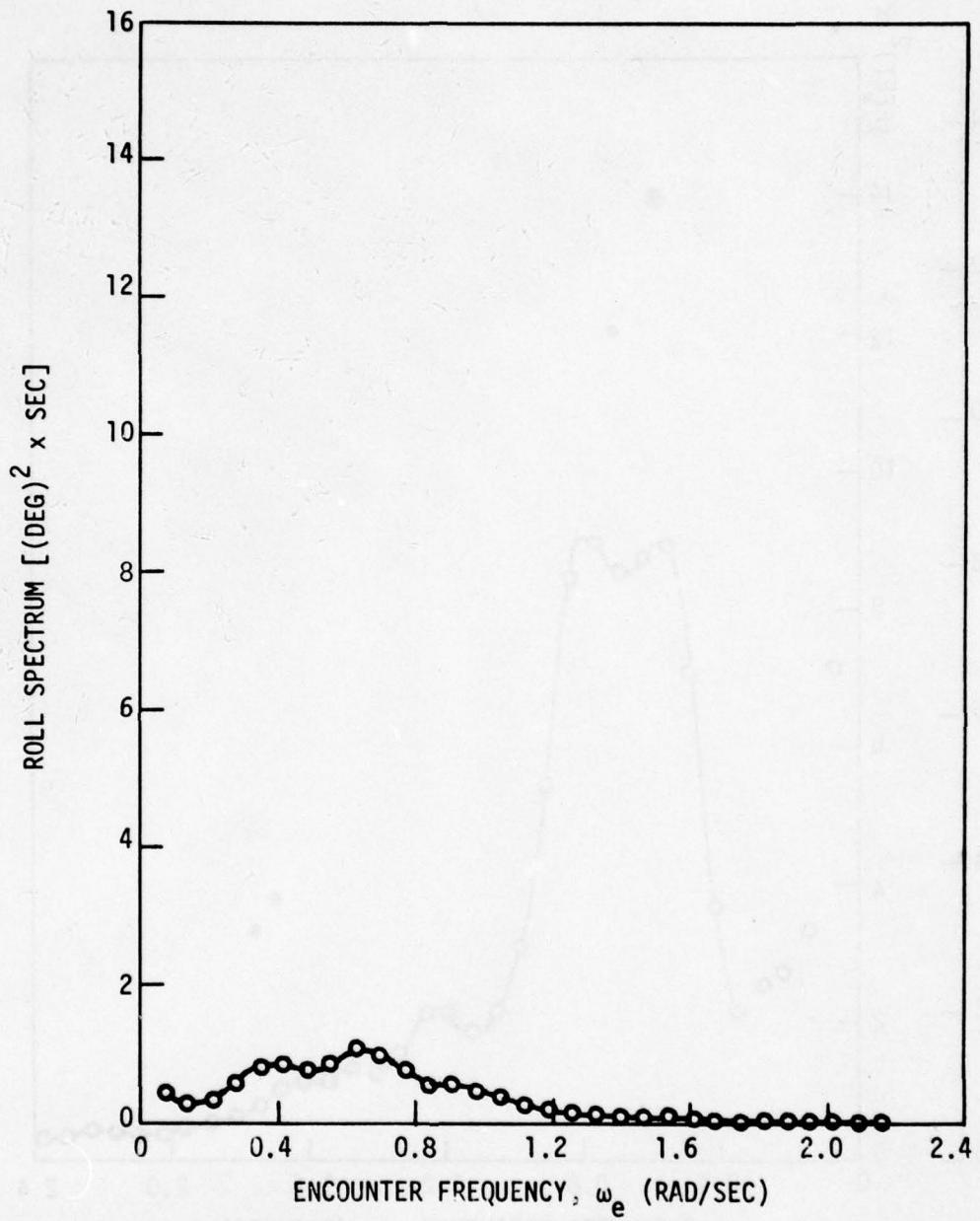


Figure 23 - Roll Spectrum for Run 9 (Head Sea)

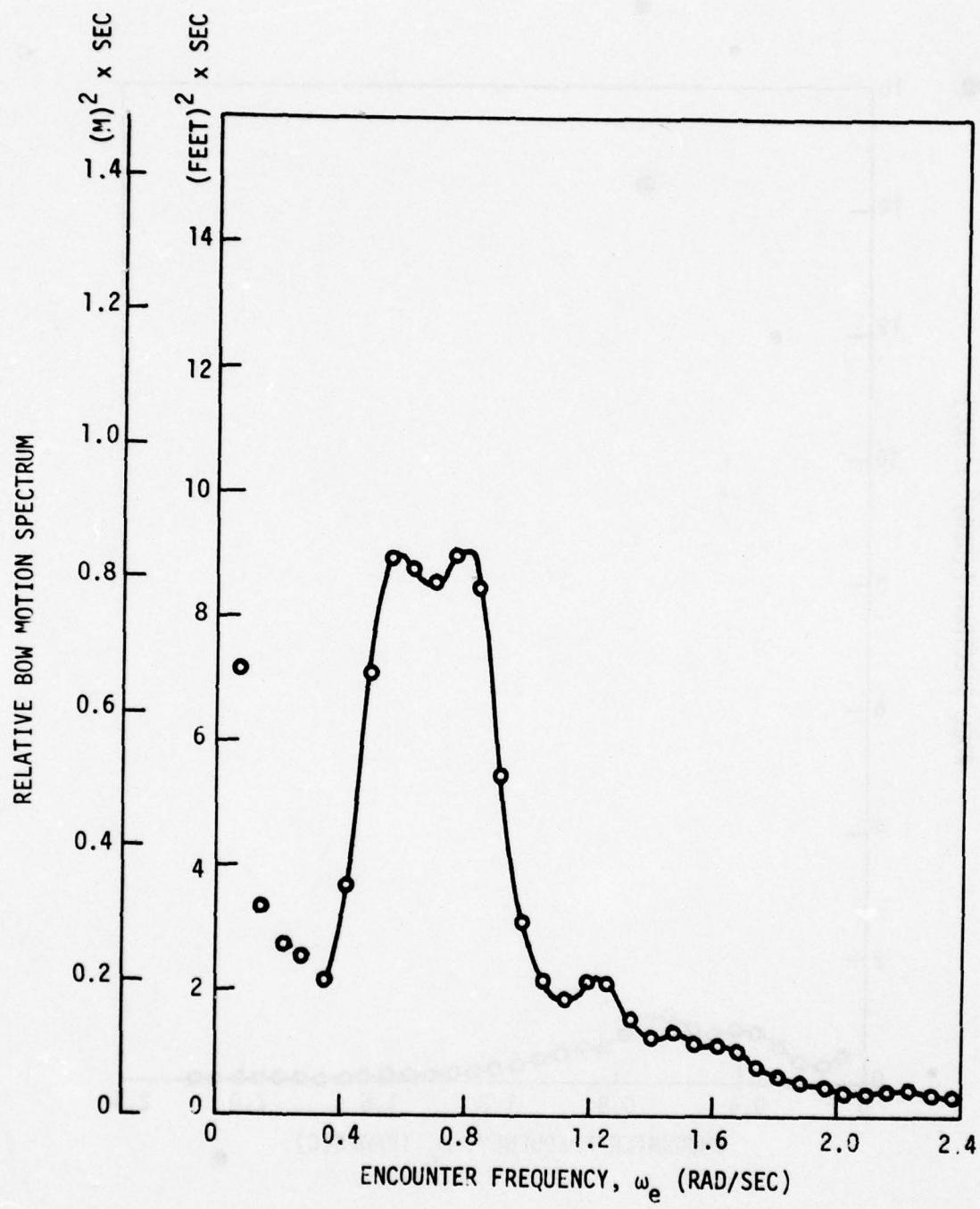


Figure 24 - Relative Bow Motion Spectrum for Run 9 (Head Sea)

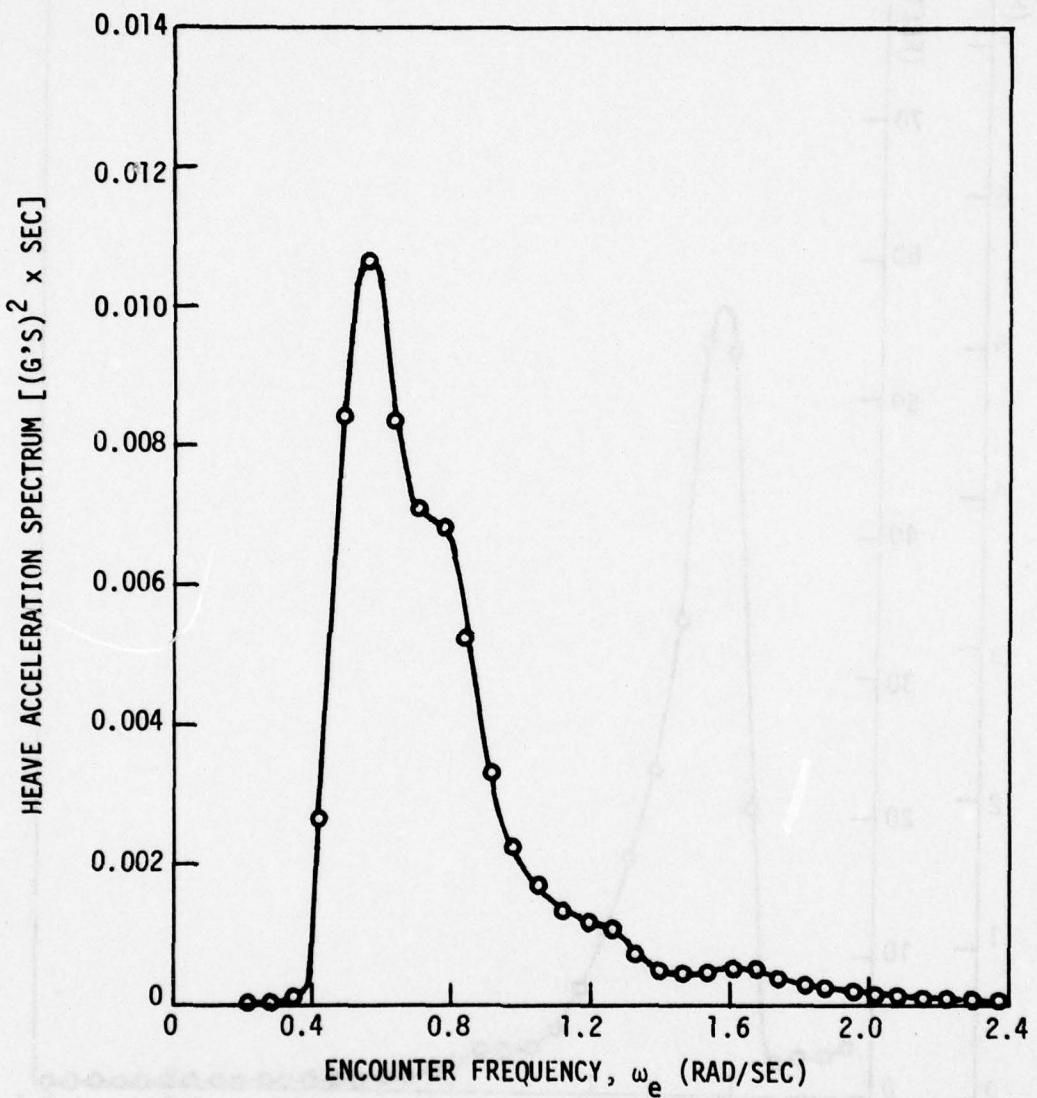


Figure 25 - Heave Acceleration Spectrum for Run 9 (Head Sea)

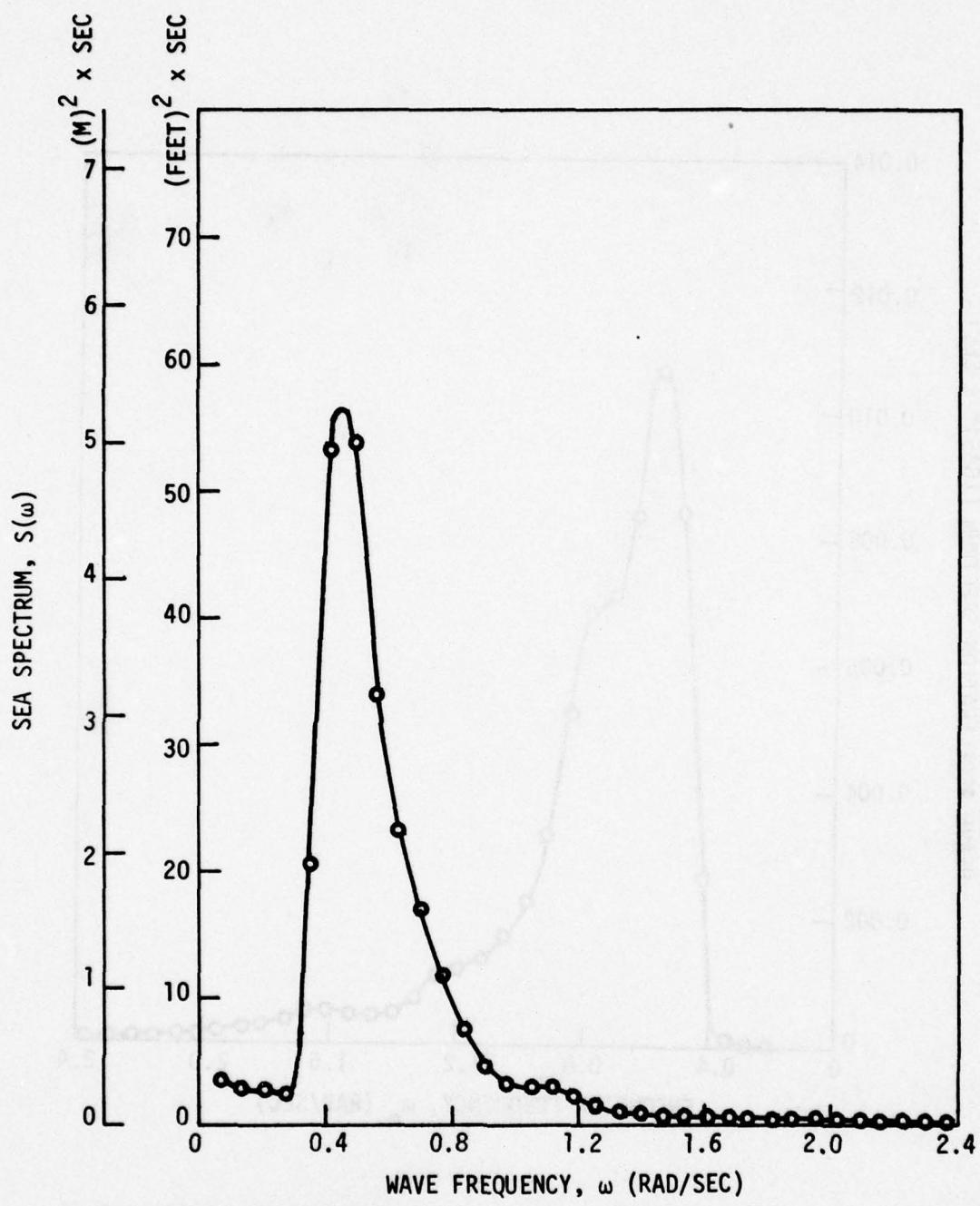


Figure 26 - Sea Spectrum for Run 10

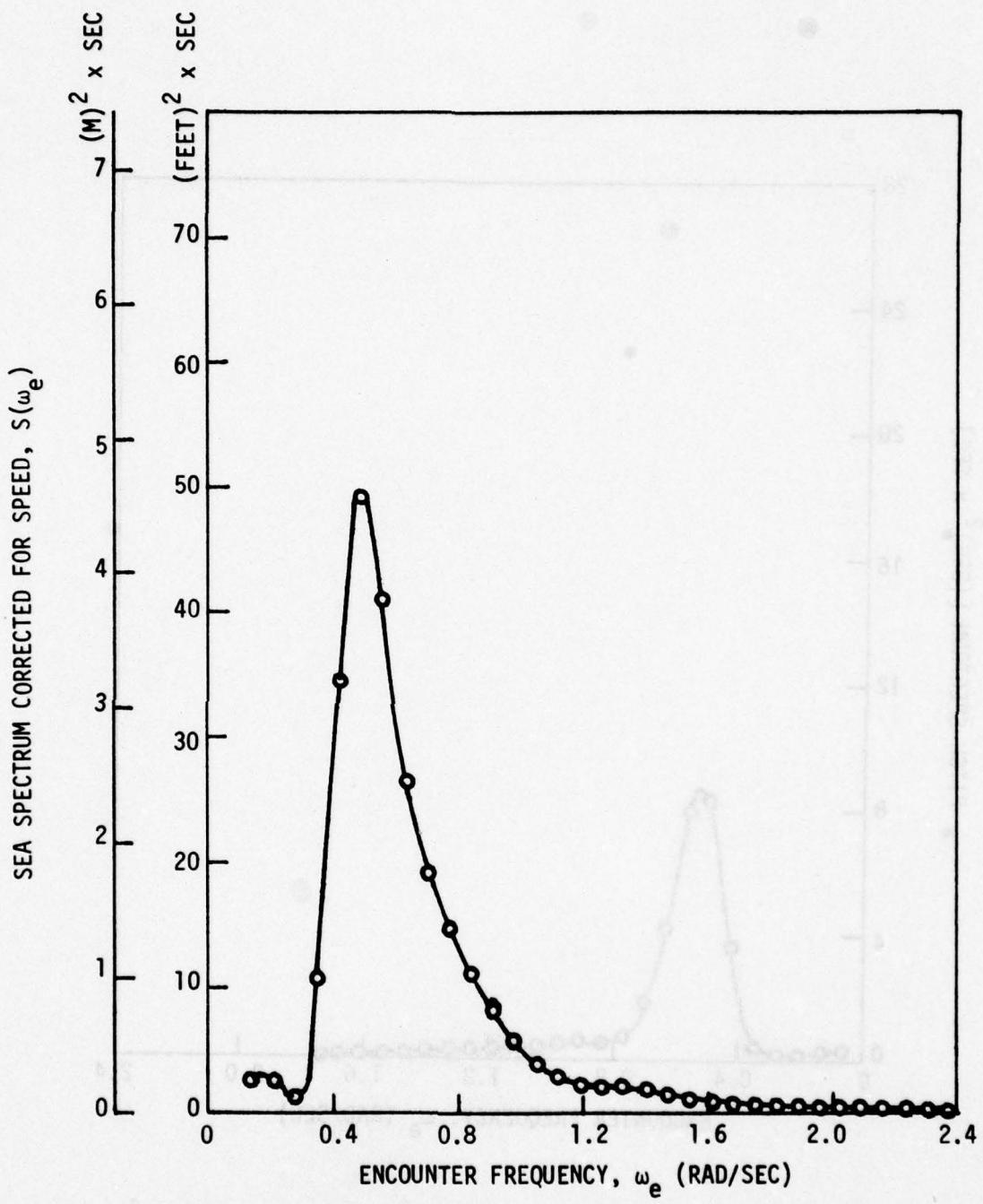


Figure 27 - Sea Spectrum Corrected for Speed for Run 10
(Starboard Bow Sea)

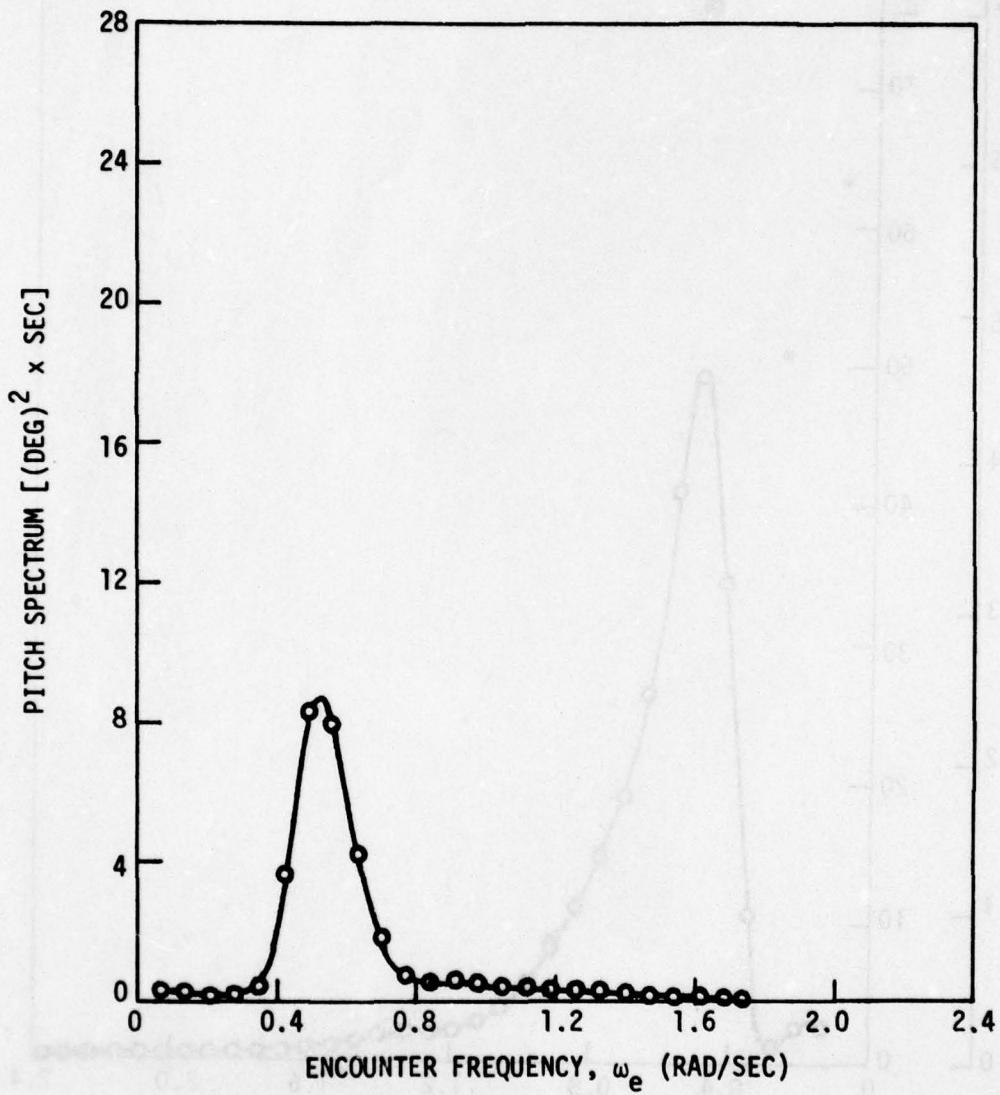


Figure 28 - Pitch Spectrum for Run 10 (Starboard Bow Sea)

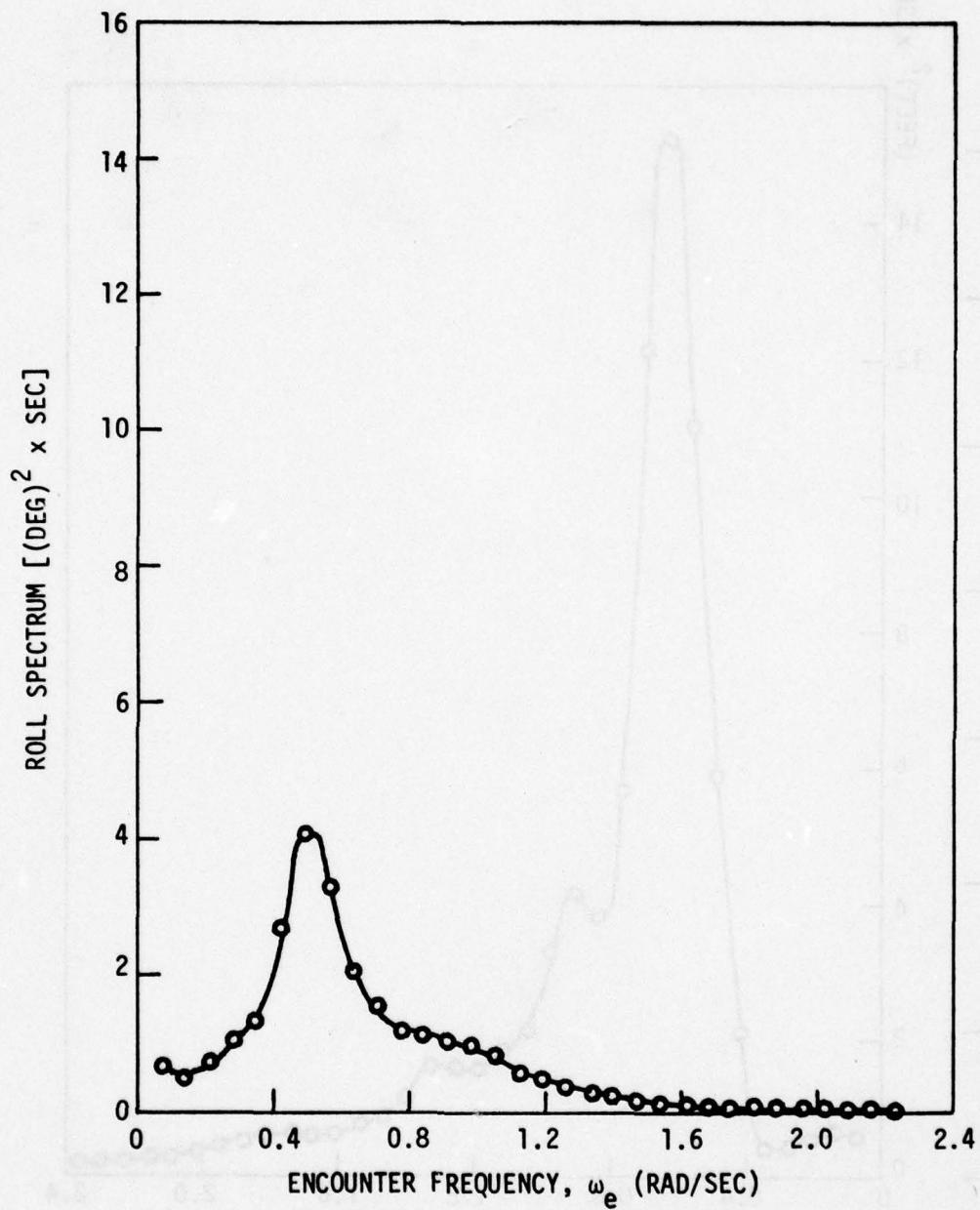


Figure 29 - Roll Spectrum for Run 10 (Starboard Bow Sea)

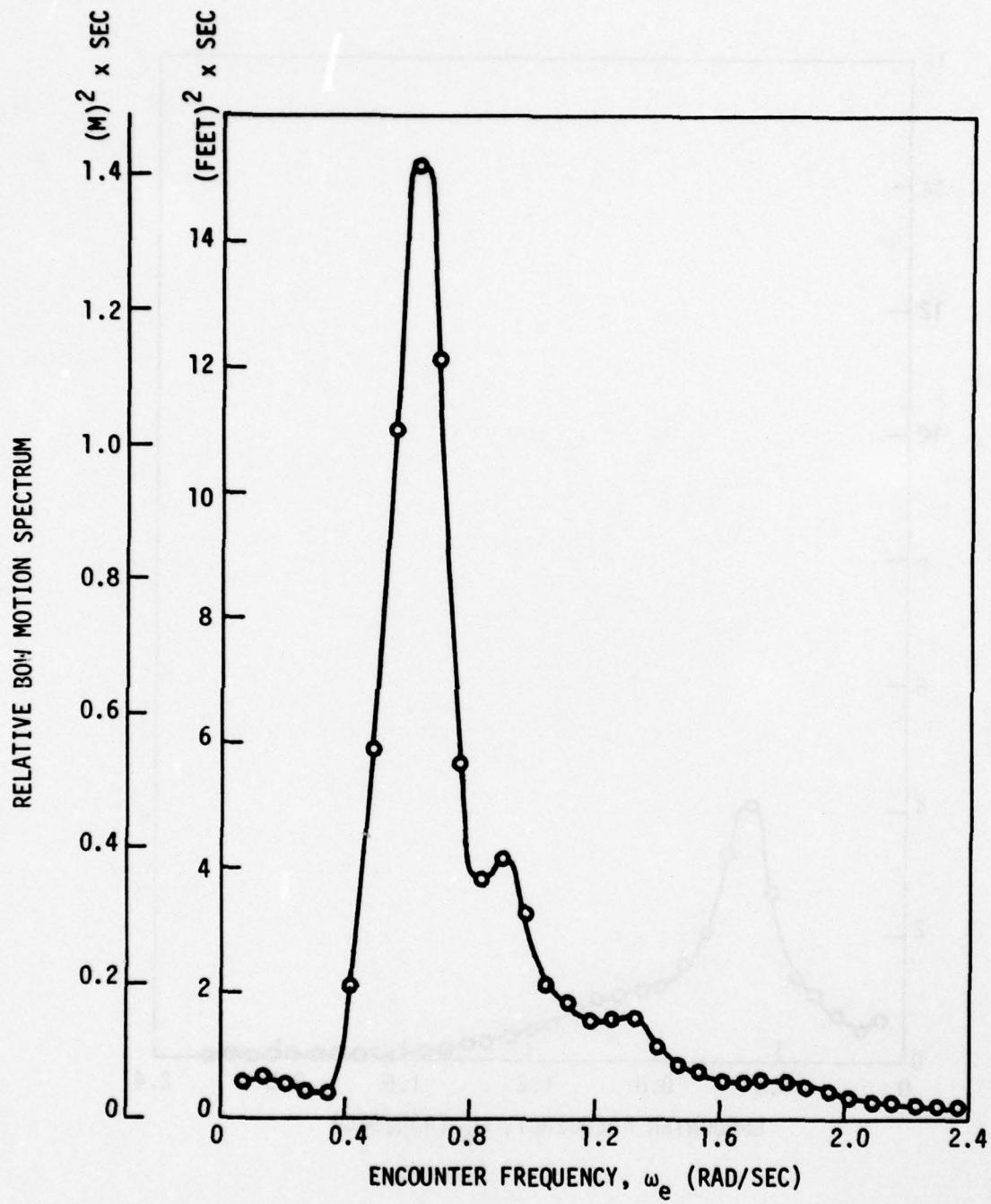


Figure 30 - Relative Bow Motion Spectrum for Run 10
(Starboard Bow Sea)

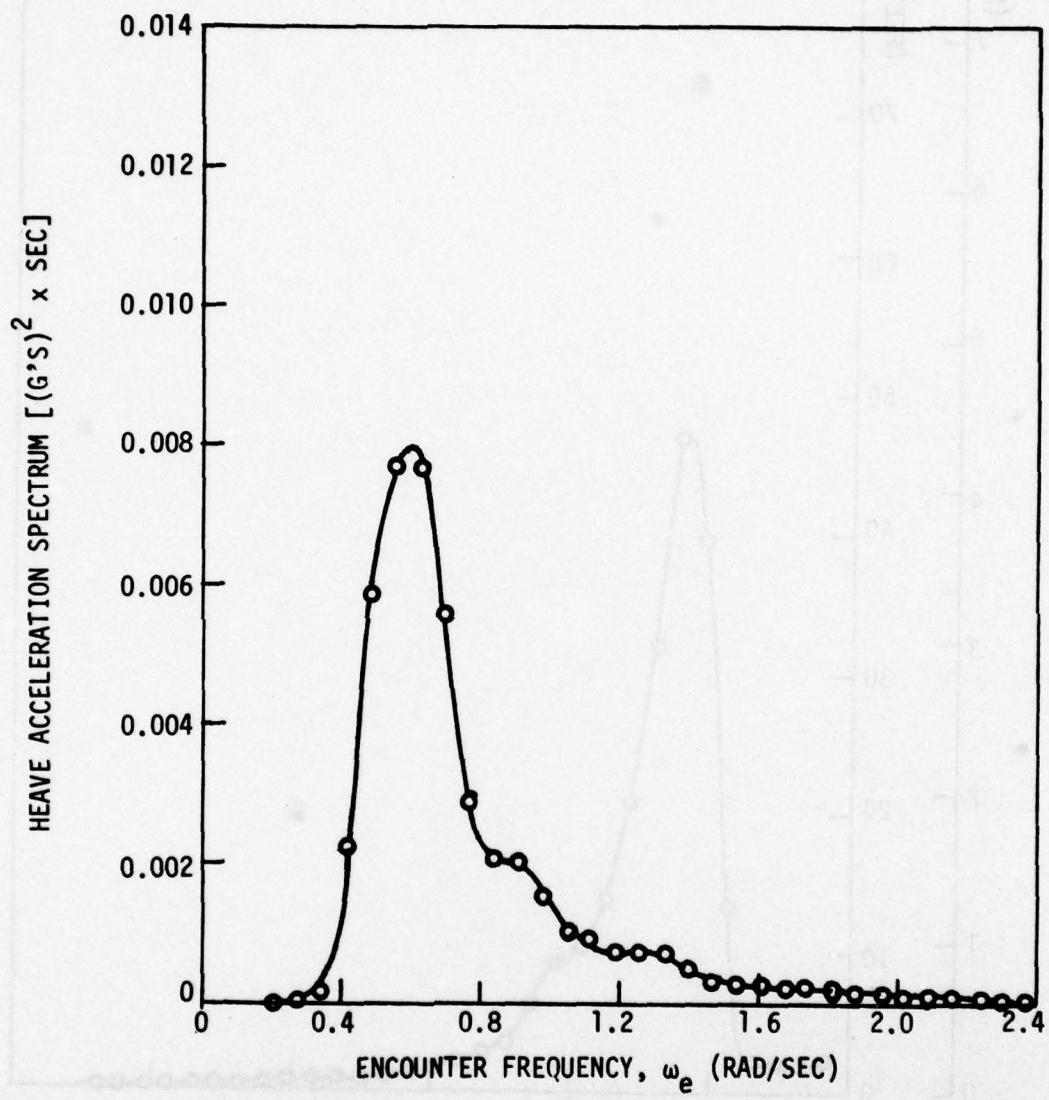


Figure 31 - Heave Acceleration Spectrum for Run 10
(Starboard Bow Sea)

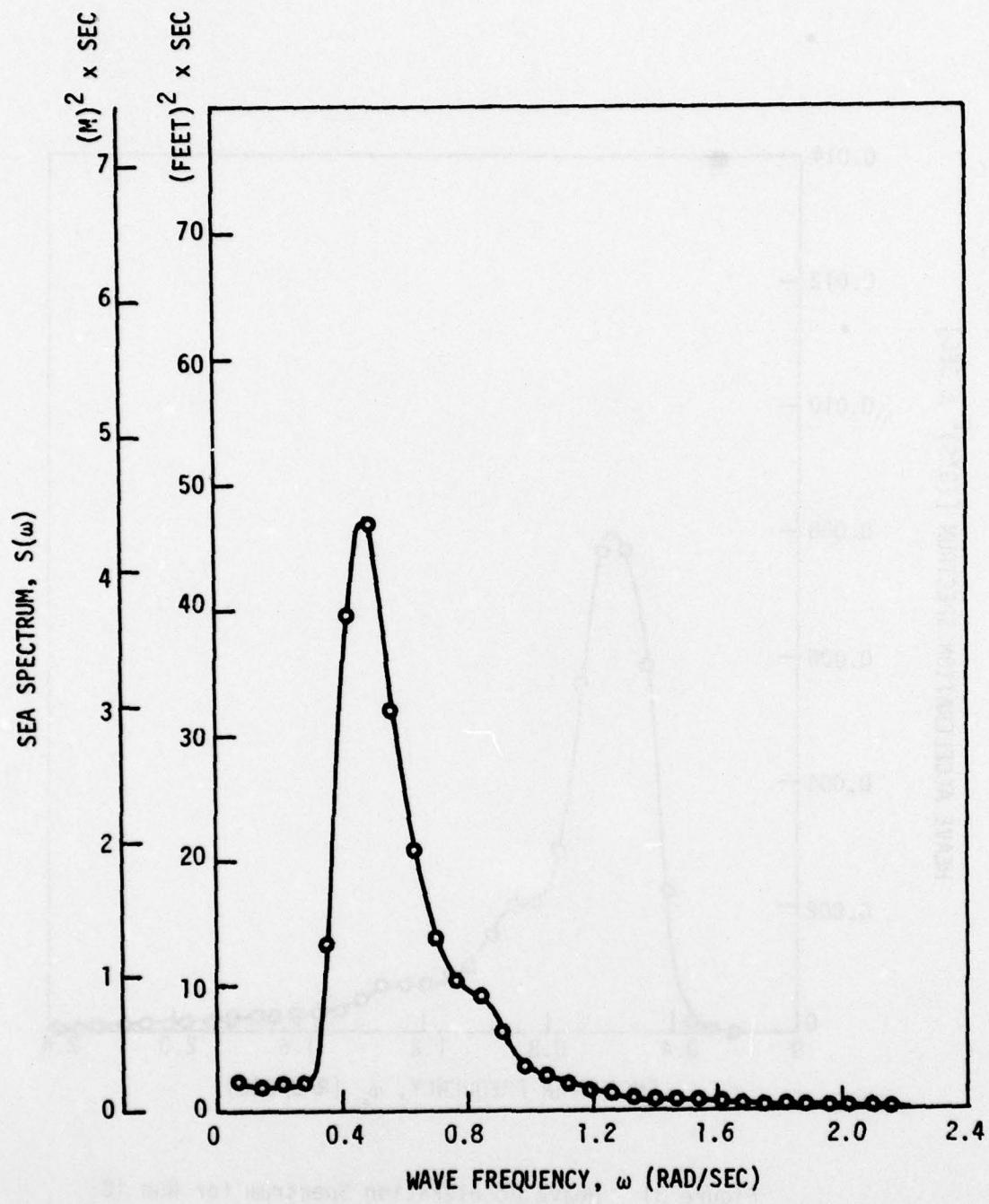


Figure 32 - Sea Spectrum for Run 11

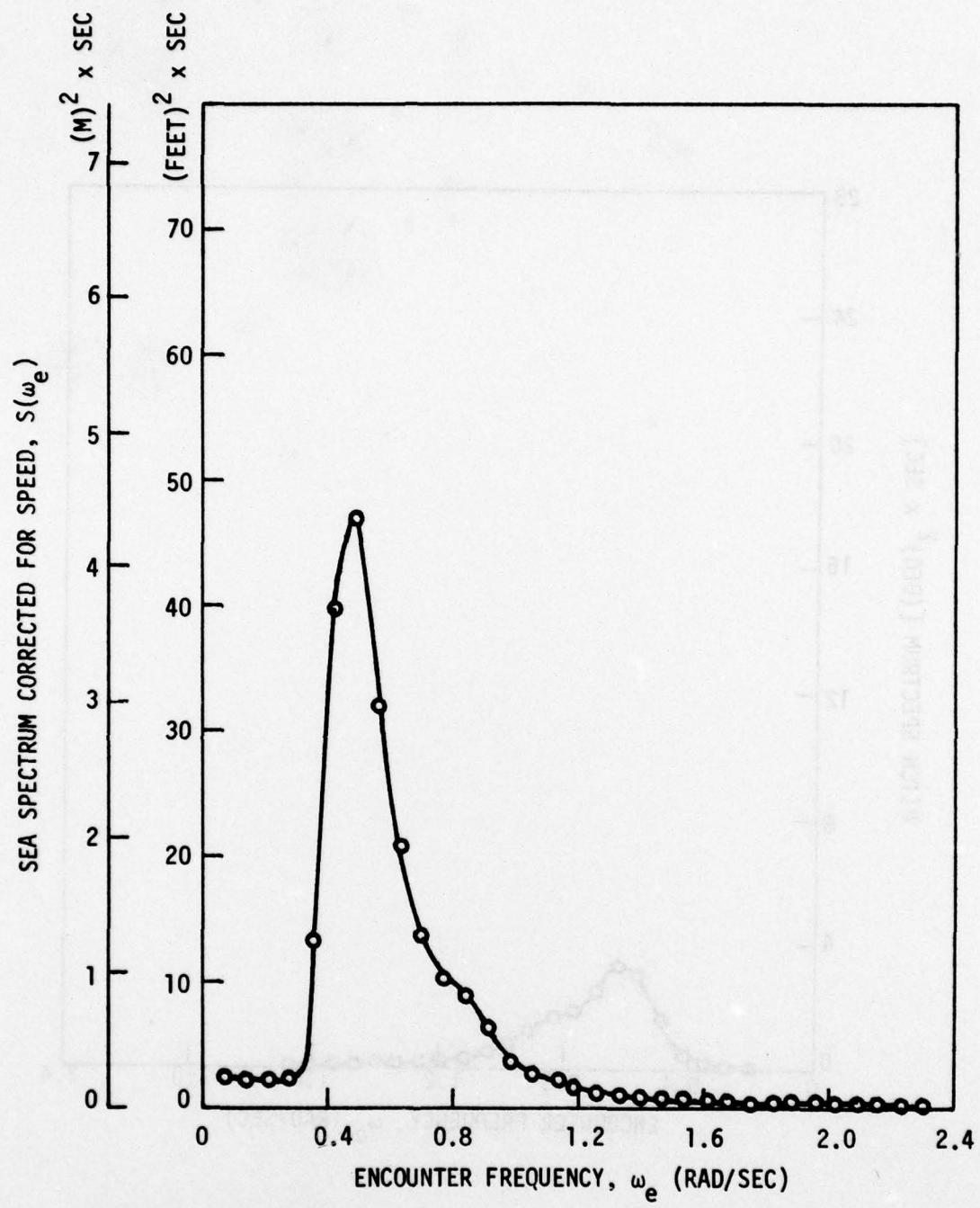


Figure 33 - Sea Spectrum Corrected for Speed for Run 11 (Beam Sea)

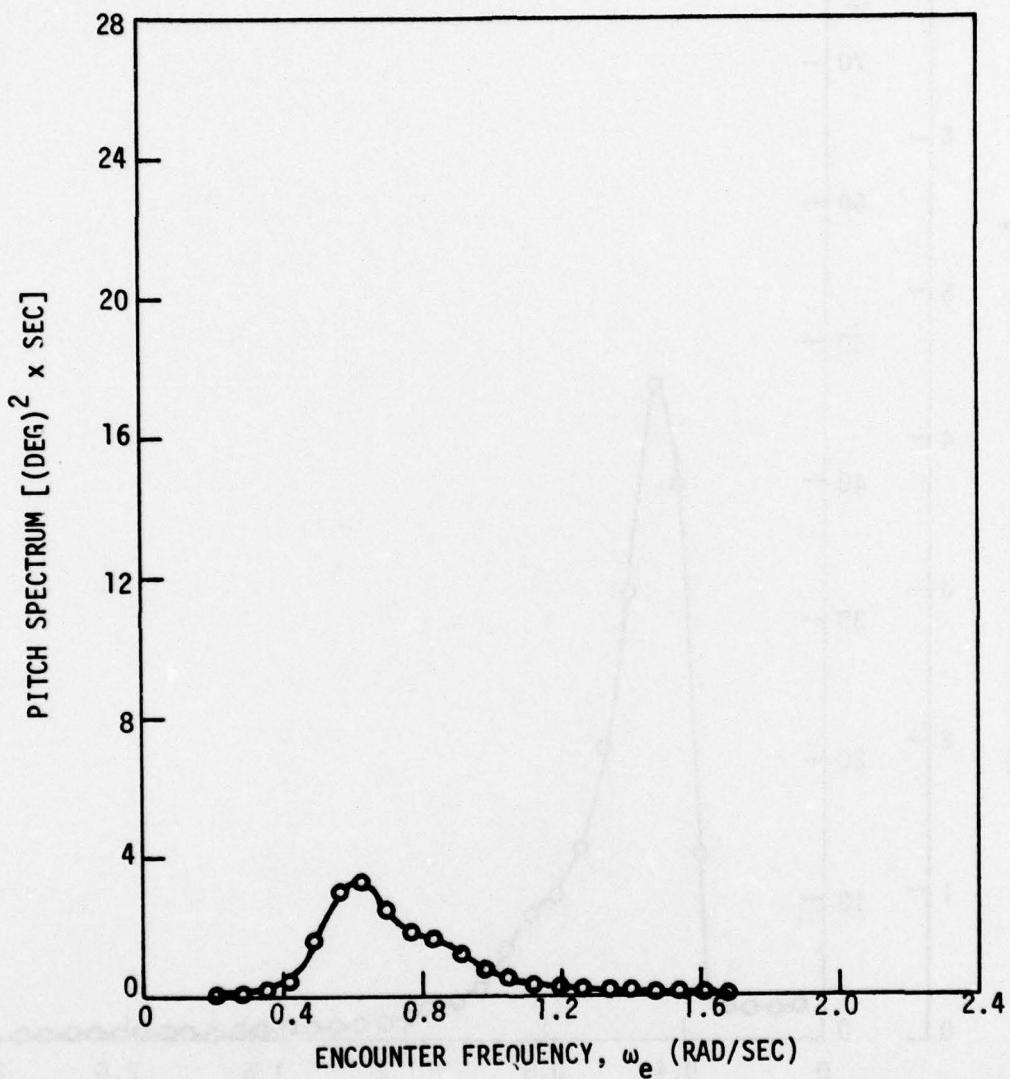


Figure 34 - Pitch Spectrum for Run 11 (Beam Sea)

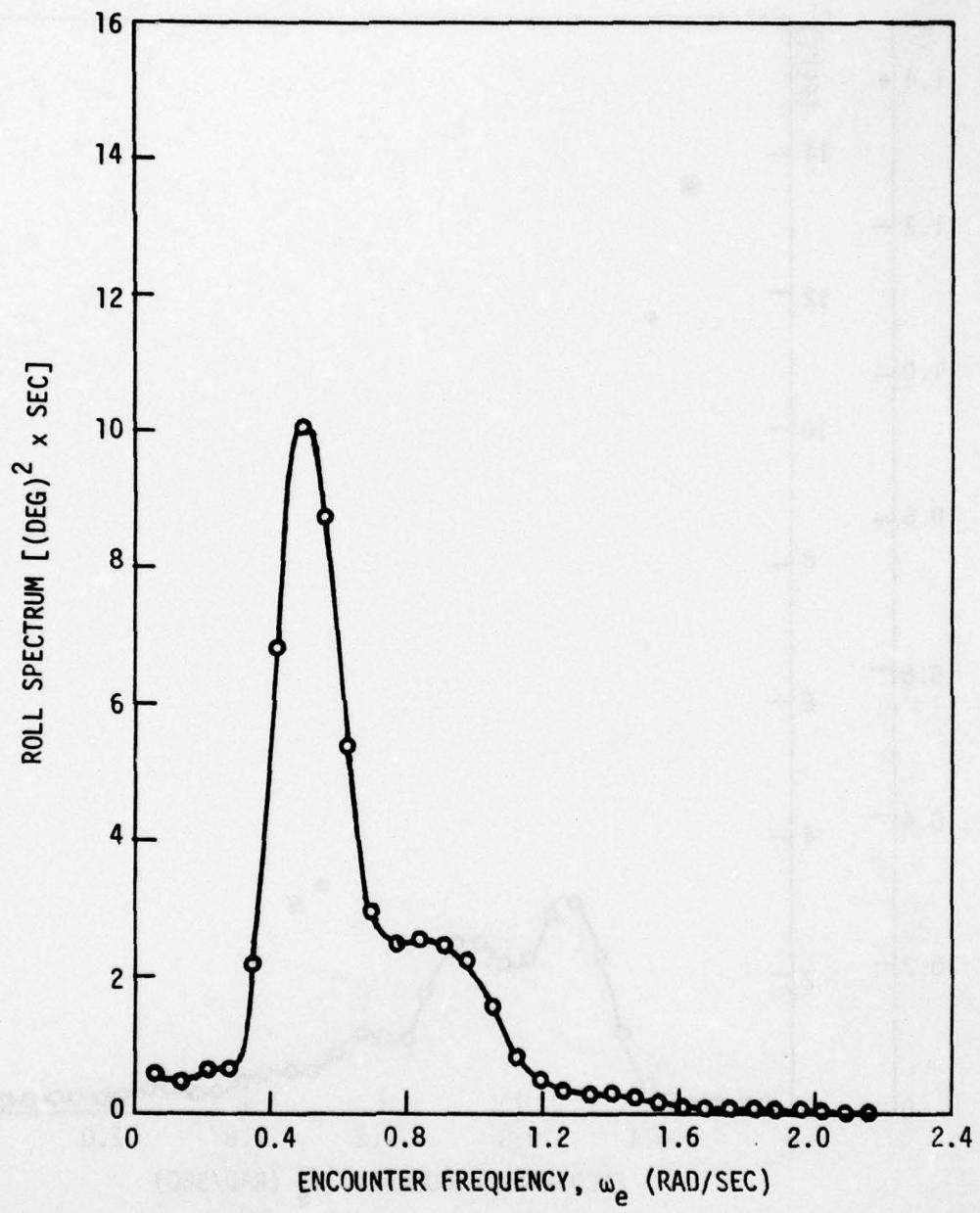


Figure 35 - Roll Spectrum for Run 11 (Beam Sea)

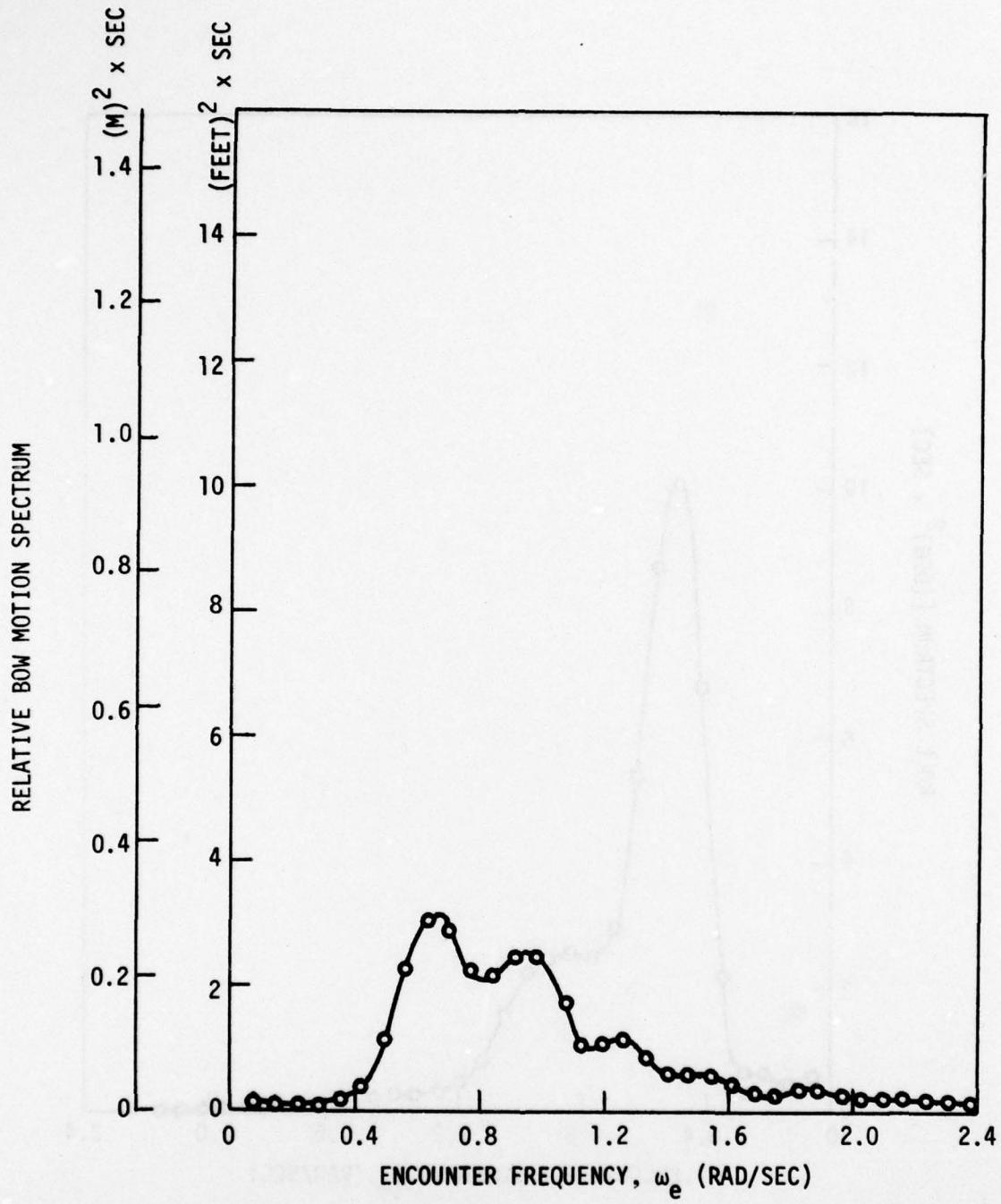


Figure 36 - Relative Bow Motion Spectrum for Run 11 (Beam Sea)

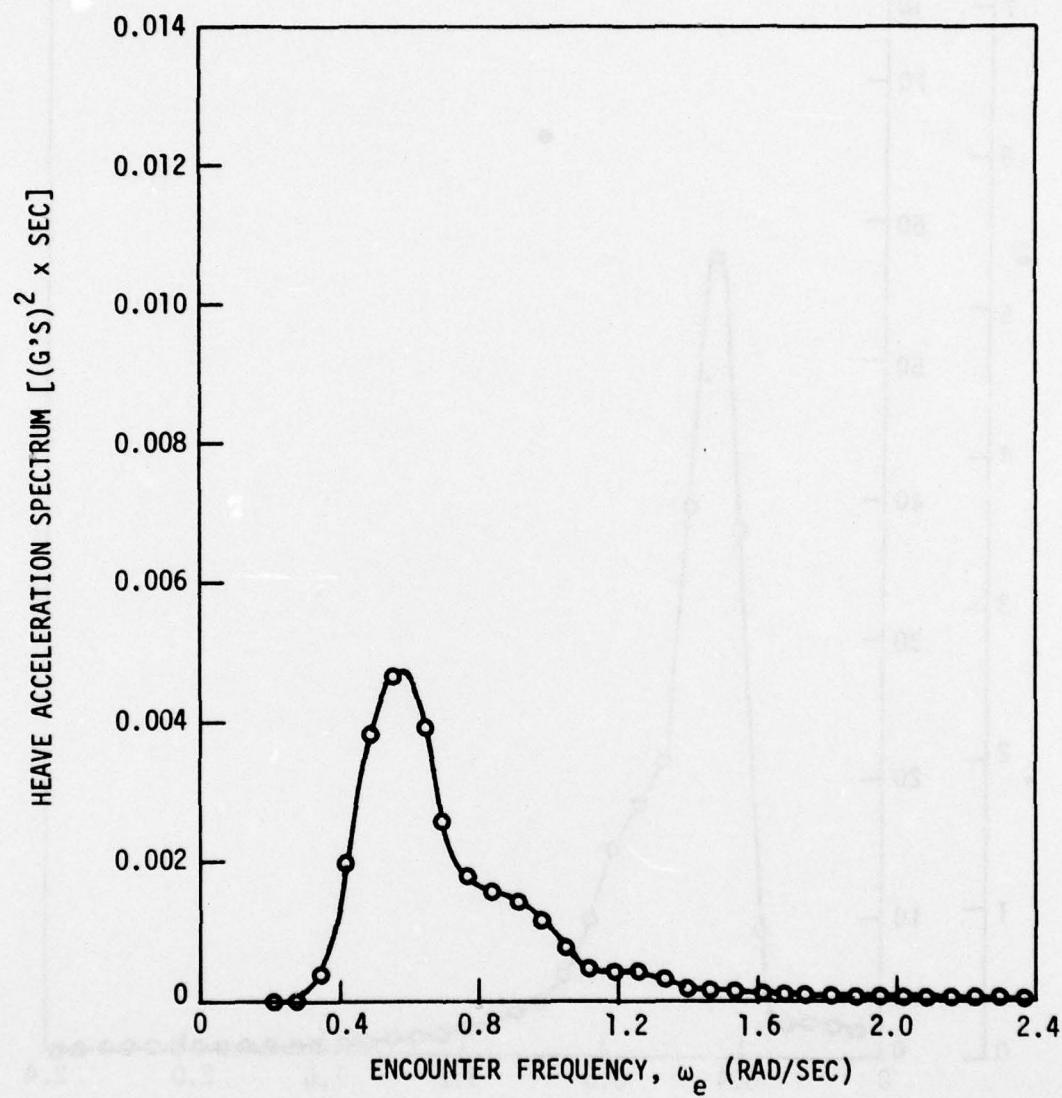


Figure 37 - Heave Acceleration Spectrum for Run 11 (Beam Sea)

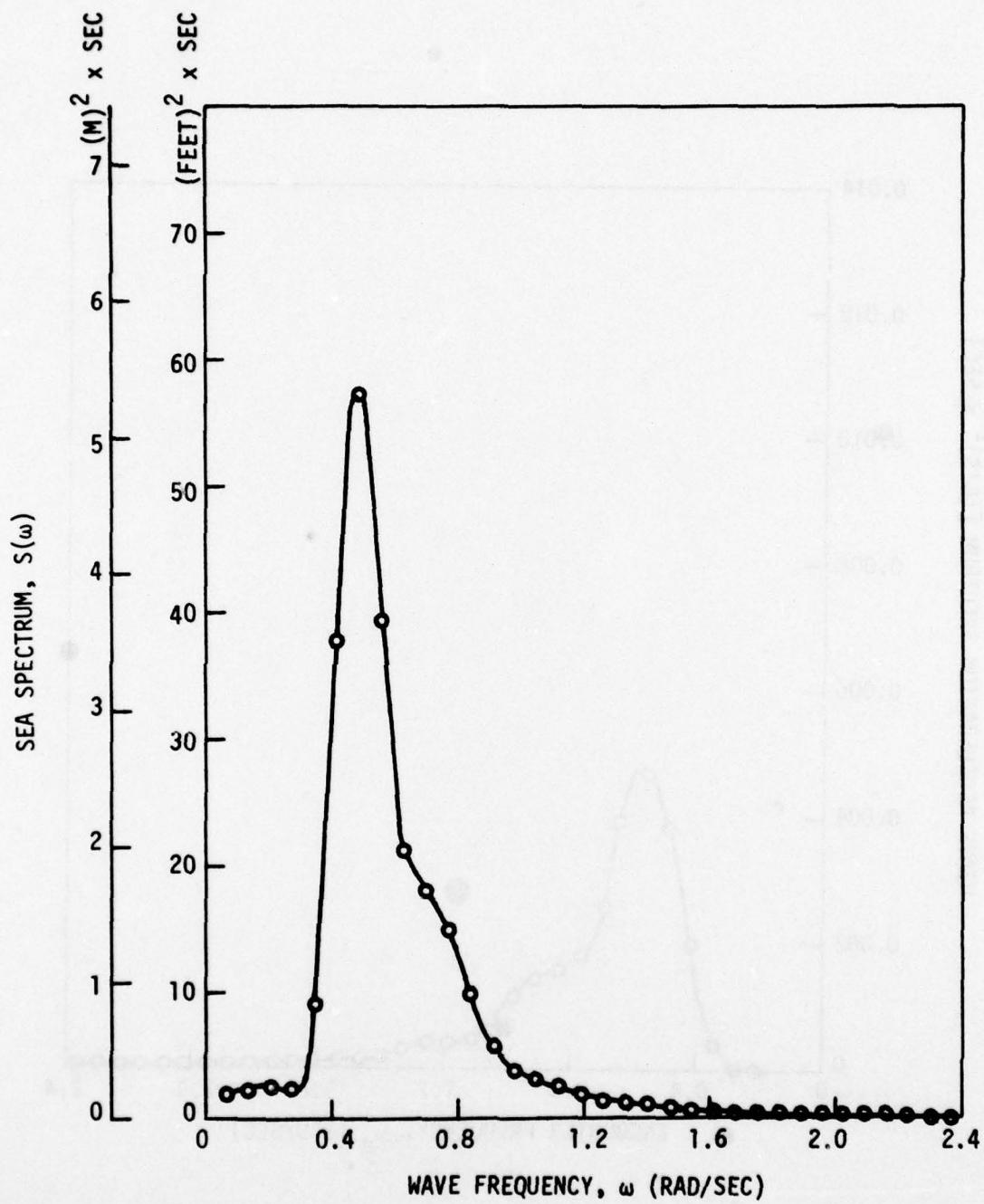


Figure 38 - Sea Spectrum for Run 12

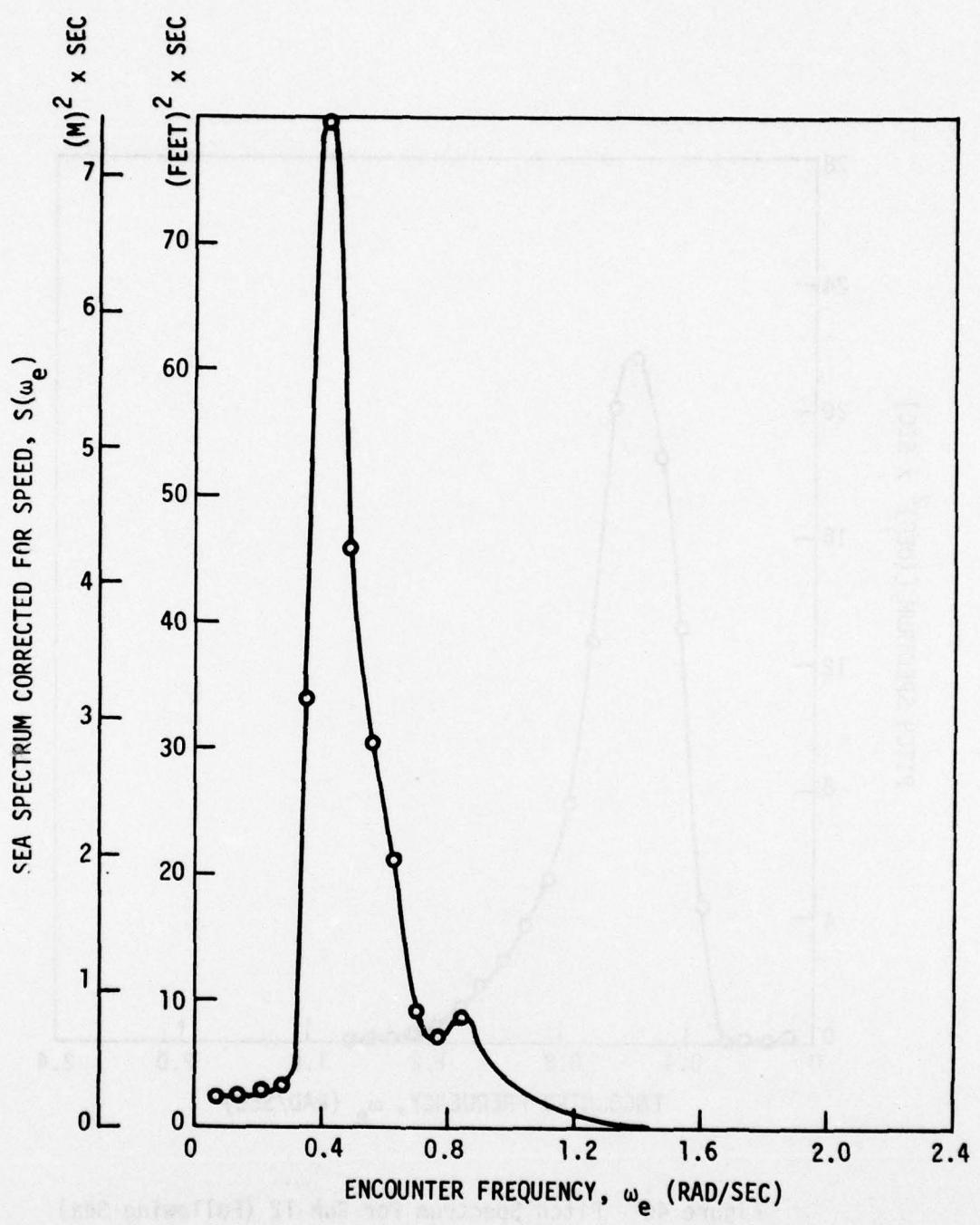


Figure 39 - Sea Spectrum Corrected for Speed for Run 12
(Following Sea)

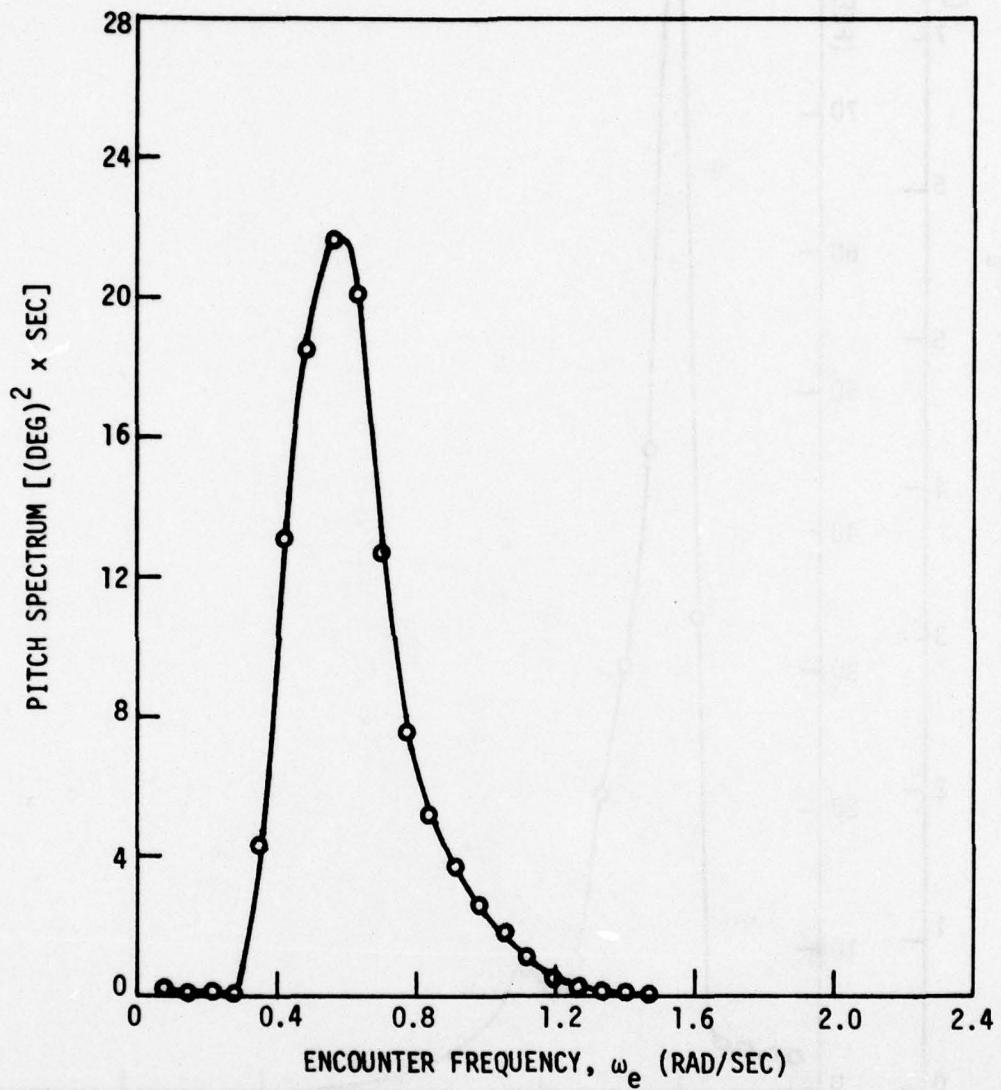


Figure 40 - Pitch Spectrum for Run 12 (Following Sea)

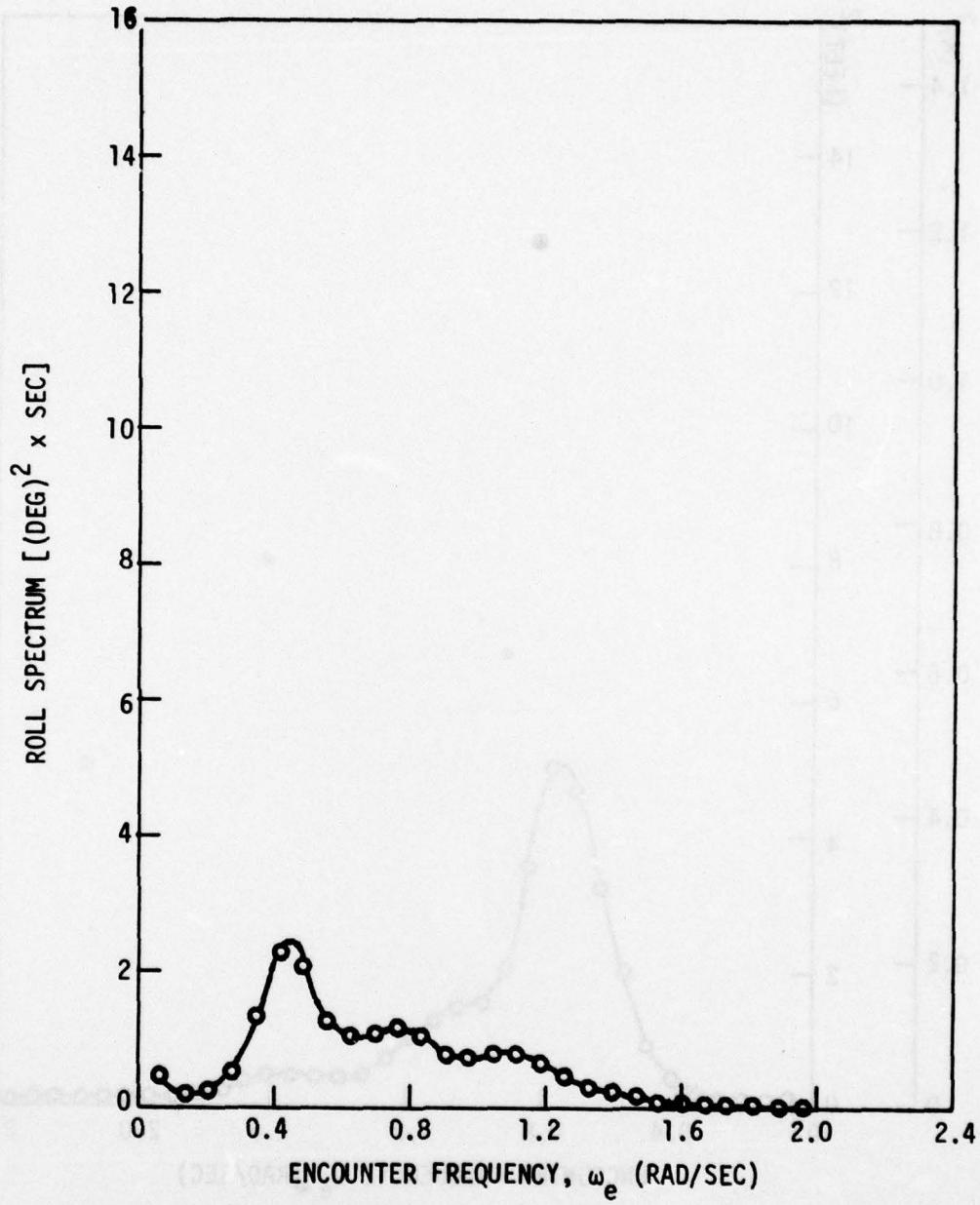


Figure 41 - Roll Spectrum for Run 12 (Following Sea)

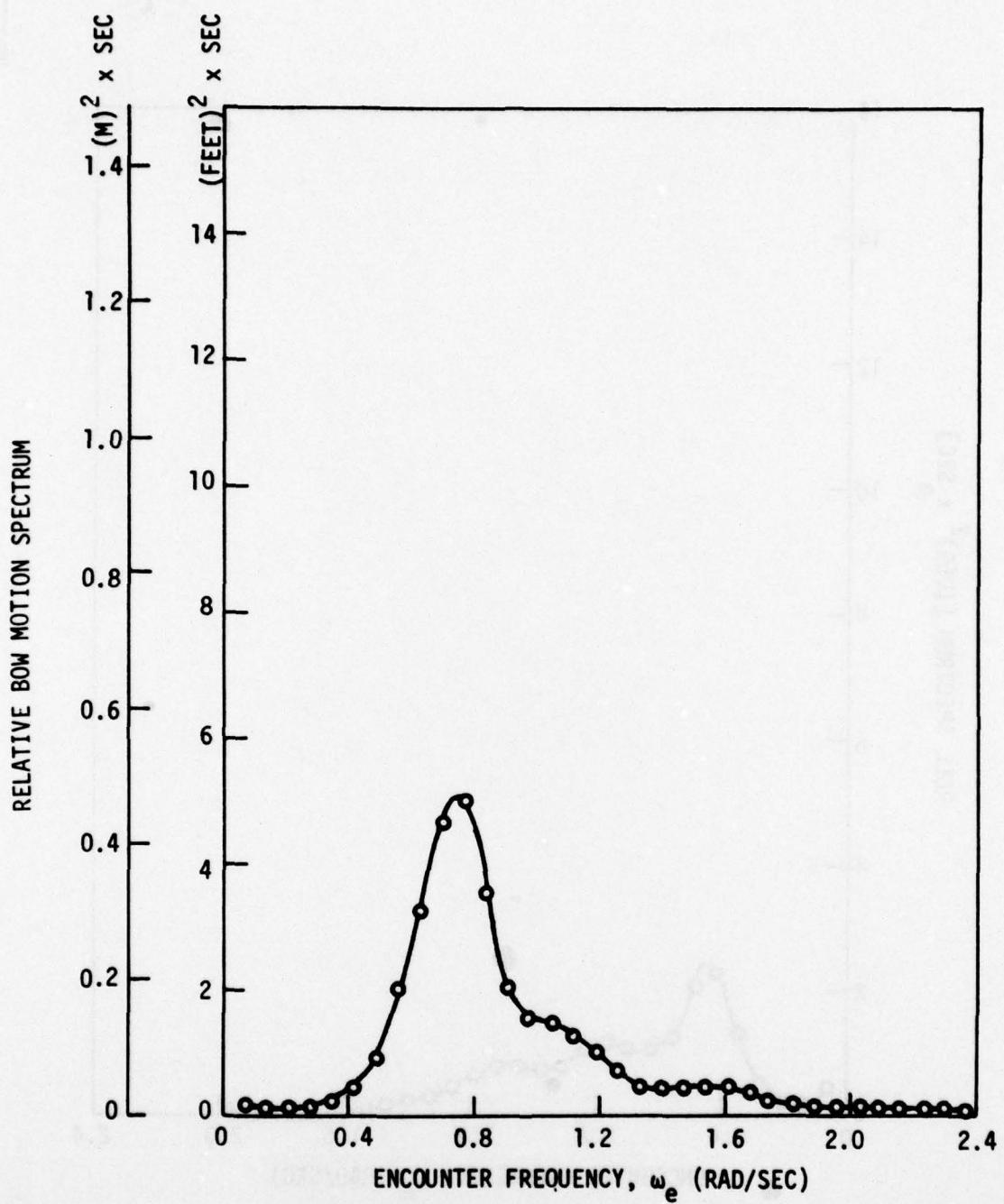


Figure 42 - Relative Bow Motion Spectrum for Run 12
(Following Sea)

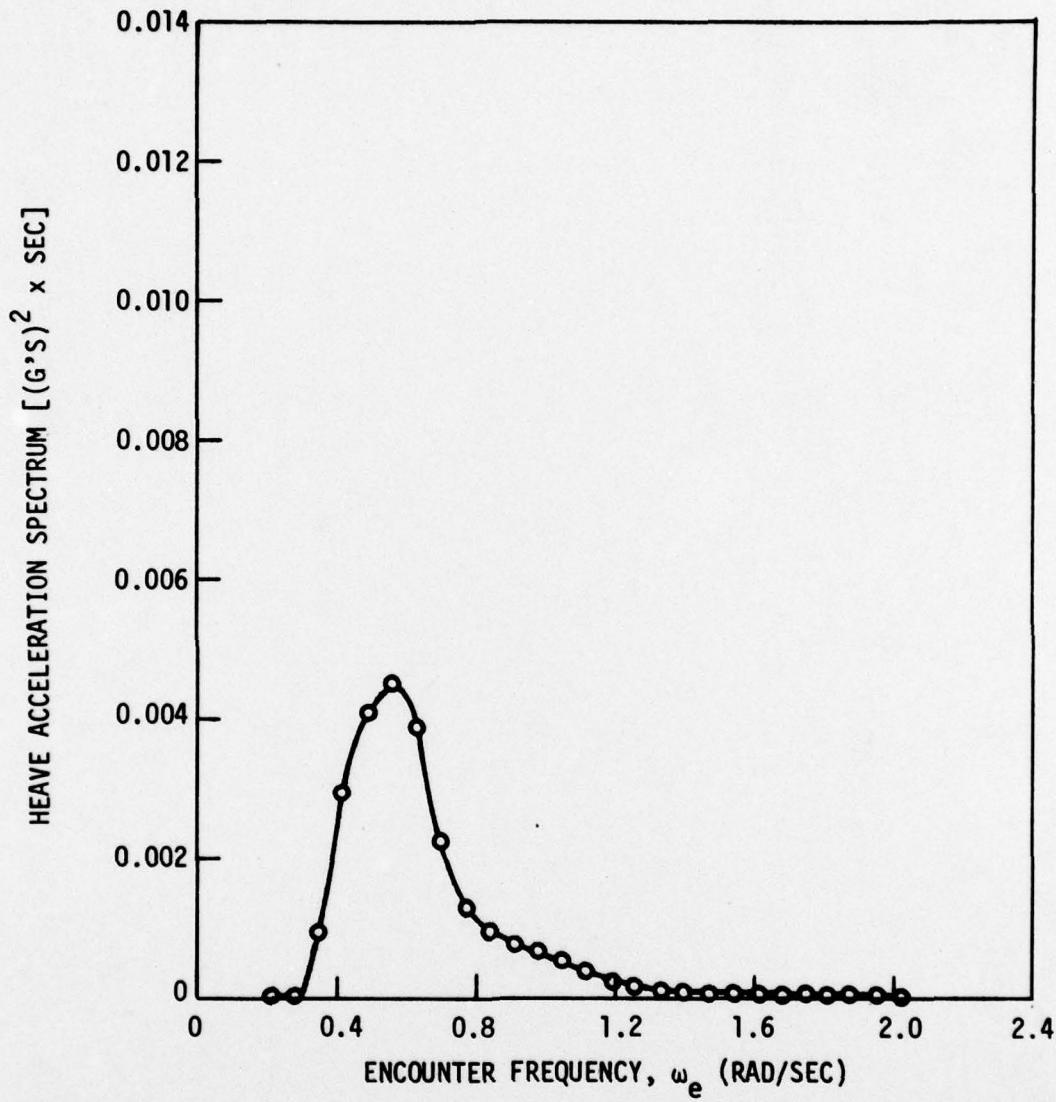


Figure 43 - Heave Acceleration Spectrum for Run 12
(Following Sea)

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